# TELL ME WHY

No:99

# GREAT
# MATHEMATICIANS
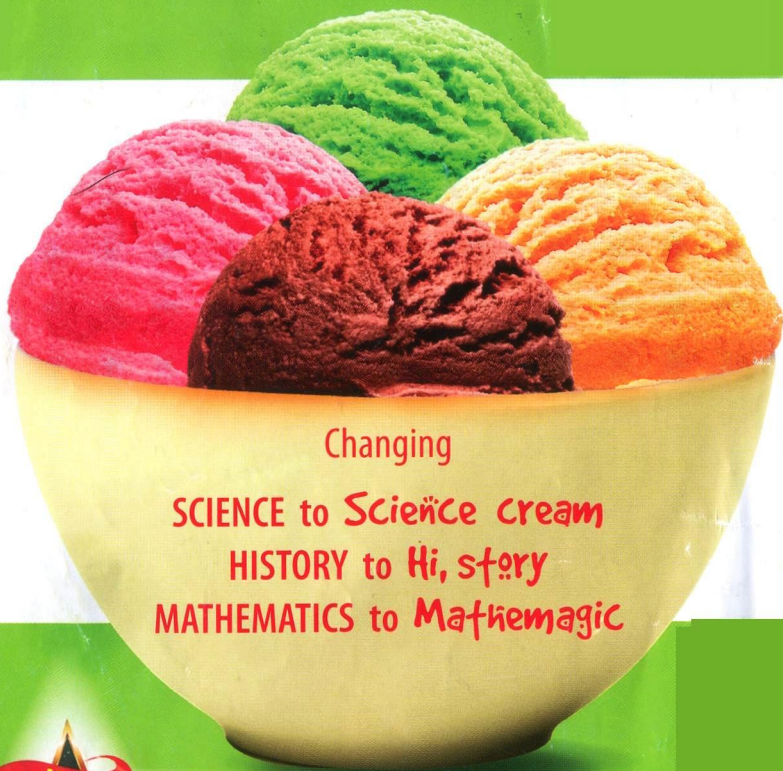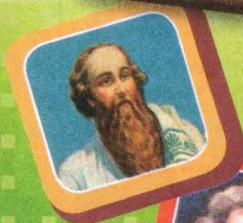
## The Story of a Queen

This is the story of a queen. We have heard the story of a Greek king who turned every object he touched into gold. Our queen is different! She never changed anything to gold, but her magic touch altered the course of history. This queen is none other than 'Mathematics' – the undisputed queen of all sciences! We cannot imagine a single branch of science where the influence of mathematics is not felt.

Over the years, mathematics has grown to be the strongest scientific discipline ever, and some great mathematicians paved the way for its present glory.

This issue of 'Tell Me Why' portrays some of the legendary mathematicians who changed the course of history, with their astonishing ability to make numbers work in magical ways.

# EARLY MATHEMATICIANS



*Thales*

## Why is Thales of Miletus called the first true mathematician?

Thales was an ancient philosopher who lived between 624 and 546 BC, in Miletus, a city in Ancient Greece that now forms a part of Turkey.

Thales is regarded as the first true mathematician, because of the many important contributions he made to the field of mathematics, especially geometry.

**Tell Me Why**

Thales used geometry to calculate the distance of a ship from the shore. He also figured out a way to measure the height of one of the Egyptian pyramids. He waited until the time of day when his own shadow was the same height that he was, and then, he measured the shadow of the pyramid, at the same time, to get its height.

Thales was able to prove several interesting mathematical ideas. He proved that a circle is bisected- or cut into halves- by its diameter, and that the angles at the base of an isosceles triangle are equal.

A triangle is a figure that has three sides, and an isosceles triangle is one that has two sides of equal length, while an angle is the shape of the space between two straight lines at the point where they meet.

Thales also proved that if two straight lines cut one another, the opposite angles are equal and that if two triangles have two angles and a side in common, the triangles are identical.

The sun is the measuring scale, and light is the unit.
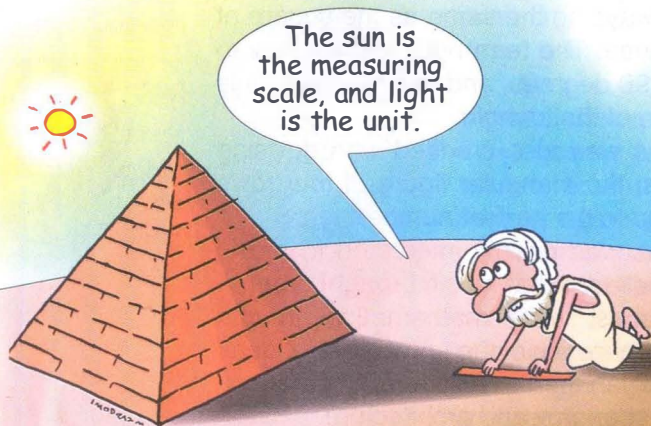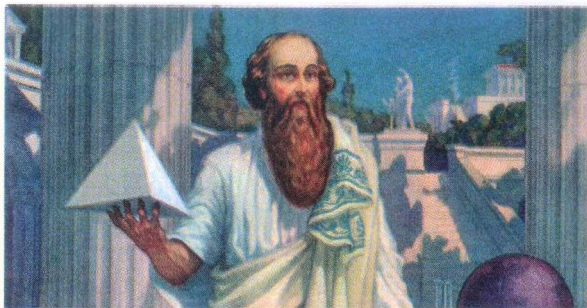
*Pythagoras*

## Why have Pythagoras' contributions changed the history of mathematics?

**P**ythagoras, who lived in Greece in the 5<sup>th</sup> century BC, had a group of disciples who followed him around, and taught other people what he had taught them.

He was a great mathematical thinker who is best known for the Pythagorean Theorem. This theorem states that in a right angled triangle, the sum of the squares of the two right-angle sides will always be the same as the square of the hypotenuse. The term right angle refers to an angle of 90 degrees, and the hypotenuse is the long side of the triangle.

Pythagoras was also credited with devising the tetractys, the triangular figure of four rows which add up to the perfect number, ten.

Pythagoras was deeply interested in music too, for he believed that music brought order to random sounds, while mathematics brought order to the mysteries of the universe! His ideas helped greatly in the development of other sciences like astronomy and architecture.

## Pythagoreanism

**P**ythagoras and his followers also founded a religion called pythagoreanism based on the belief that everything in the universe is related to numbers. He and his followers had to face a lot of persecution for these beliefs.

> Sorry, I can't live without you!

√2

## Why is the sto y of Hippasus a sad story?

**H**ippasus was a student of Pythagoras, who is credited with discovering irrational numbers.

An irrational number is a number that cannot be written as a fraction while a rational number is one that can be expressed as a simple fraction.

According to one story, Hippasus was idly toying with the number $\sqrt{2}$, attempting to find the equivalent fraction. Eventually, he came to realize that no such fraction existed, and that $\sqrt{2}$ is an irrational number. Hippasus must have been overjoyed by his discovery, but sadly, his master was not.

Pythagoras had defined the universe in terms of rational numbers, and the existence of irrational numbers brought his theory into question. Poor Hippasus was sentenced to death by drowning, instead of being congratulated!

## Why is the work of Democritus important?

Democritus, a great philosopher of Ancient Greece, was a pioneer of mathematics and geometry, who lived in the latter part of 4ᵗʰ century BC. He is best known for his atomic theory. He developed the concept of the 'atom' which is the Greek word for indivisible.

Democritus believed that everything in the world was made up of atoms that were microscopic and indestructible. He was among the first to observe that a cone or pyramid has one-third the volume of a cylinder or prism respectively, with the same base and height.

Democritus also understood that the Milky Way was a collection of stars, and that space was limitless. He produced works with titles like 'On Numbers', 'On Geometrics', 'On Tangencies', 'On Mapping' and 'On Irrationals'. Unfortunately, his works were destroyed during the Middle Ages.

*Statue of Democritus*
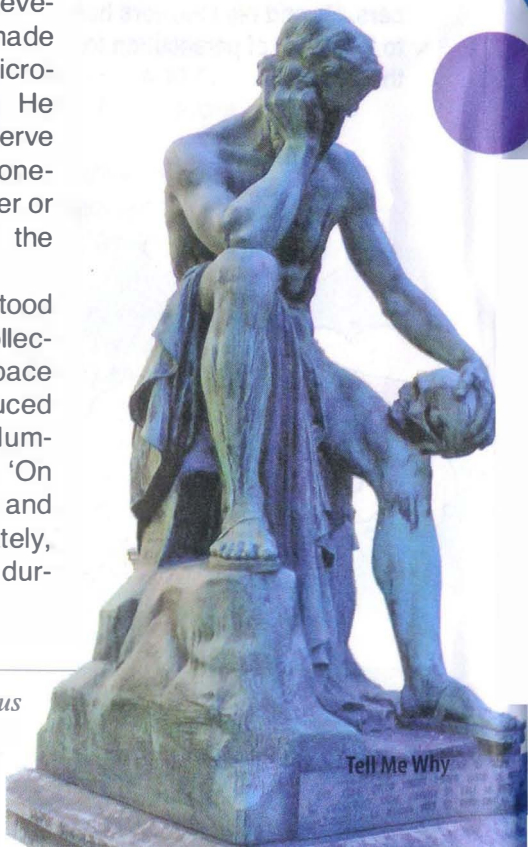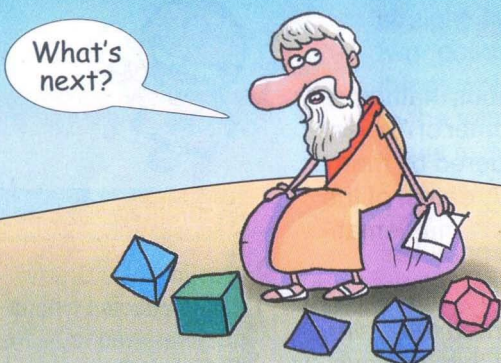
## Why are Plato's contributions to mathematics unique?

**P**lato was one of Ancient Greece's most important mathematicians. He was a brilliant student of another great Greek philosopher, Socrates. Plato founded his Academy in Athens in 387 BC, where he stressed mathematics as a way of understanding more about reality.



*Plato*

He also believed that geometry was the key to unlocking the secrets of the universe. Plato is perhaps best known for his identification of five regular, symmetrical three dimensional shapes, which he maintained were the basis for the whole universe, and which have become known as the Platonic Solids.

Plato was also influenced by Pythagoras, and both of them believed that the shape of the universe is spherical. Plato's contributions to the field of mathematics are truly outstanding and unique.
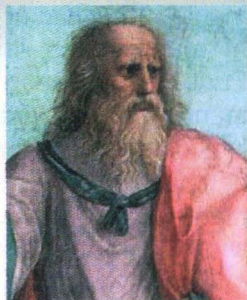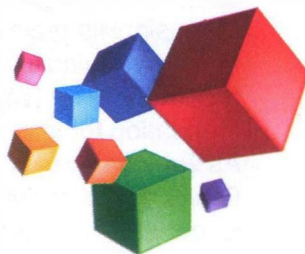
## Who was Eudoxus?

**E**udoxus, a famous mathematician and astronomer of Ancient Greece, is considered by many people to be the greatest of the classical Greek mathematicians.

Many craters on the Moon and Mars are named after him, in recognition of his achievements in the field of astronomy. In mathematics, the work of Eudoxus has been quoted by many great scholars in the field, including successors like Hipparchus. Eudoxus studied mathematics from Archytas, who was a follower of Pythagoras.

One of the questions that Eudoxus was interested in was the problem of duplicating the cube. He was also interested in number theory, and the theory of music. His main contribution to mathematics is the theory of proportion- he also laid the foundation for integral calculus. As was the case of many other Greek mathematicians and philosophers, his written works have not survived the rigours of time.
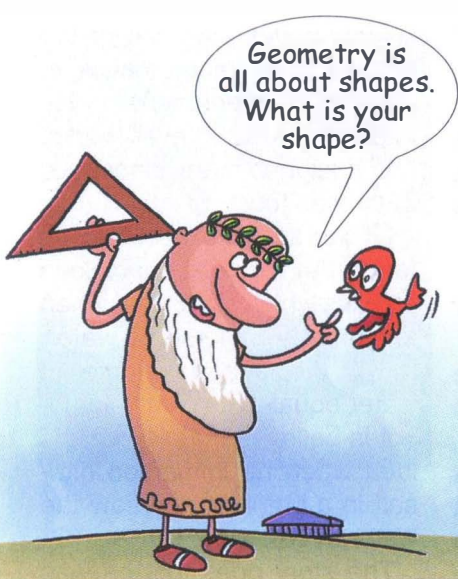
*Eudoxus*

Geometry is all about shapes. What is your shape?

straight line between any two points, and that two things which are both equal to the same thing, are also equal to each other.

Euclid's later books teach more advanced maths, including how triangles and circles work, irrational numbers, and three-dimensional geometry. Though some of his works are lost, at least five of them have survived to this day.

## What is the role of Euclid in mathematics?

Euclid is one of the most influential mathematicians of all time. He wrote 'Elements,' which, for centuries, has been one of the main text books for teaching geometry.

Euclid understood the importance of logic and reason in mathematics. We still have copies of Euclid's books today, and they begin with basic definitions, and then go on to geometry to prove, for instance, that all right angles are equal, that you can draw a

## CURIOUS FACT

### What's in a name?

Do you know that 'Euclid' is the English version of a Greek name? In Greek, the mathematician's name meant 'renowned' or 'celebrated'.

## What do we know about Archimedes?

The name Archimedes is familiar to anyone who has studied mathematics. He was one of the titans of mathematics who lived in Ancient Greece. His work paved the way for modern calculus.

It was Archimedes who gave us theorems that help us to calculate the area of a circle, the surface area and volume of a sphere, and the area under a parabola. He proved that the volume and surface area of the sphere are two thirds that of the cylinder, including its bases.

Archimedes was one of the first to apply mathematics to physical phenomena. He explained how a lever works, and designed many innovative machines too.

Of course, he is most famous for the Archimedes principle in physics which states that when an object is immersed in water, it will displace a volume of water equal to its own volume.

It is believed that he got this idea when he immersed himself in a bathtub, and saw the water overflowing.

The story goes that he was so excited by his discovery that he ran straight out in to the street, unclad, shouting 'Eureka' which means, roughly, 'I found it'!
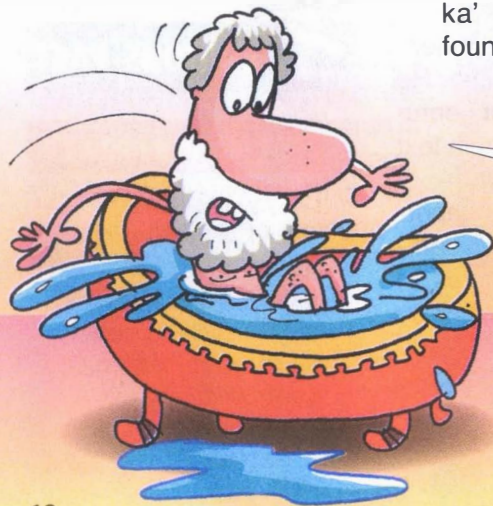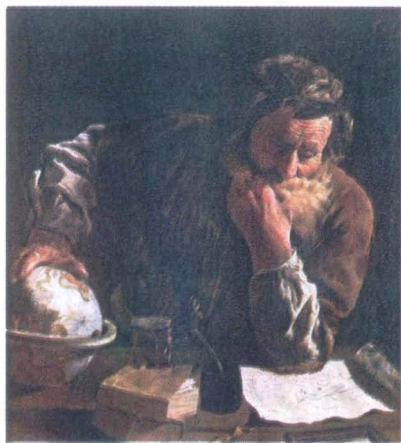
Oh! EUREKA!

*Archimedes*

## Why was Eratosthenes considered a multifaceted personality?

Eratosthenes, who was born in 276 BC, is most famous as the founder of geography. He worked as chief librarian of the Alexandrian Library in Egypt, and was also known as a writer, an astronomer, a mathematician, and a poet. He died in 194 BC.

Chief among his discoveries in mathematics are a method of calculating the circumference of the Earth, and the development of a mathematical sieve named after him. This sieve is a method used to find all prime numbers below a certain value.

Eratosthenes made a calendar with leap years, a 675-star catalogue, and maps. He had a great interest in history as well.

Eratosthenes was truly a multifaceted personality for the excellence he displayed in fields as diverse as poetry, astronomy, geography, history and mathematics.
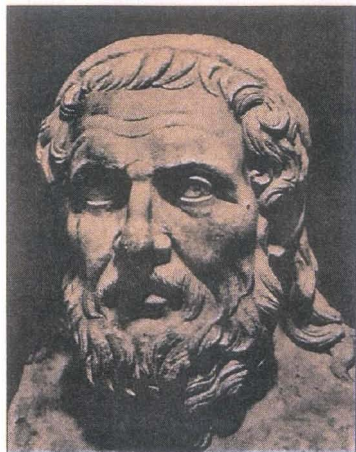
*Apollonius*

## Who was Apollonius?

Apollonius was an Ancient Greek mathematician from Perga who influenced many later scholars including Ptolemy, Francesco Maurolico, Johannes Kepler, Isaac Newton, and Rene Descartes. His methodology and terminology were unique, especially in the area of conics.

A solid cone can be cut into sections, producing several unusual forms. Apollonius examined these conic sections, noted their shapes, and introduced the terms ellipse, hyperbola, and parabola to describe them. He was the first to recognize that these three forms, along with the circle, are all part of any cone.

His work 'Conics', is considered one of the greatest scientific works of the ancient world. His theory of conic sections is still useful to engineers and mathematicians.

Apollonius formulated a theory to explain the apparent motion of the planets, and the varying speed of the Moon. In fact, he was interested in lunar history, and even has a crater on the Moon named after him!
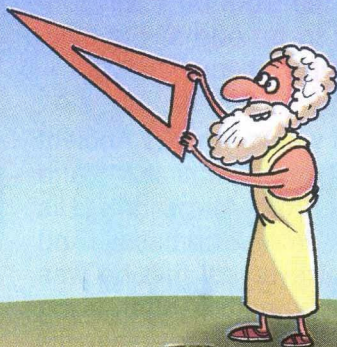
## Why is Hipparchus remembered to this day?

**H**ipparchus is remembered as the 'father of trigonometry'. He was born in 190 BC, in what is now Turkey.

He developed trigonometry, constructed trigonometric tables, used trigonometry to calculate how far away the Moon was from the Earth, and to work on the problem of whether the Earth went around the Sun or the Sun went around the Earth. Hipparchus had started by using Euclid's geometry to figure out the movements of the Earth, the Moon, and the Sun. However, he soon realized that Euclid's geometry was meant for things that stood still, not the heavenly bodies that moved through space.

He began to develop a mathematical system that would work for moving objects. We call this system trigonometry which means 'measuring triangles', but it's really a system for measuring changes in the size of triangles.
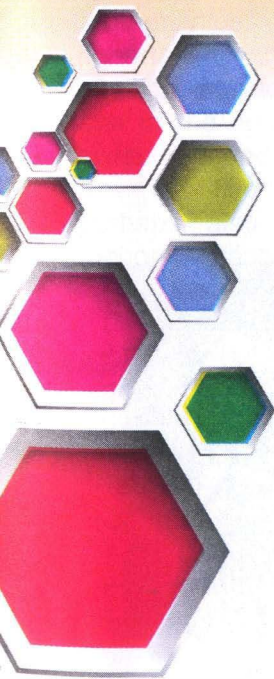
## Why is the work of Heron considered to be one of the milestones of mathematics?
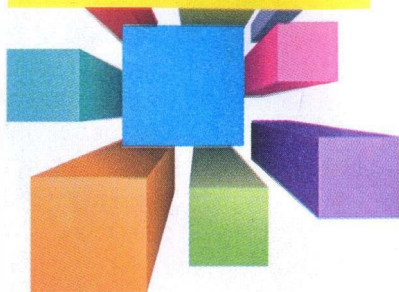
**H**eron was a famous Ancient Greek mathematician and inventor from Alexandria. His writings in mathematics and mechanics reveal that he was practical by nature, often using ingenious means to attain his goal, such as his design for a steam engine, war catapults, and various machines for lifting, that used compound pulleys and winches.

Heron taught at the University of Alexandria where, it is believed that he taught mathematics, physics, pneumatics, and mechanics.

He wrote many books, and these covered mathematical theories, including formulae for calculating the area of shapes and the volumes of solids, as well as good approximations of square roots and cube roots.

Heron's works contain the first known references to a systematic geometric system, with standard terminology and symbols. Heron lived at the beginning of the first century AD.
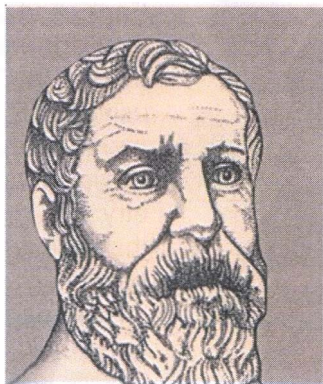


*Heron*

## What are Diophantus' contributions to mathematics?

**D**iophantus, who lived in the 3rd century AD, is considered as 'the father of algebra'. He wrote a series of books called the 'Arithmetica'. They were a collection of algebraic problems, which greatly influenced the subsequent development of number theory.

Diophantus also made important advances in mathematical notation, and was one of the first mathematicians to introduce symbolism into algebra. He was perhaps, also the first, to recognize fractions as numbers in their own right.

Diophantus applied himself to some quite complex algebraic problems, particularly what has since become known as Diophantine Analysis. Of the original thirteen books of the 'Arithmetica', only six have survived, although some Diophantine problems from 'Arithmetica' have been found in later Arabic sources.

$$x^2 + y^2 + xy$$
$$\sim y^2$$
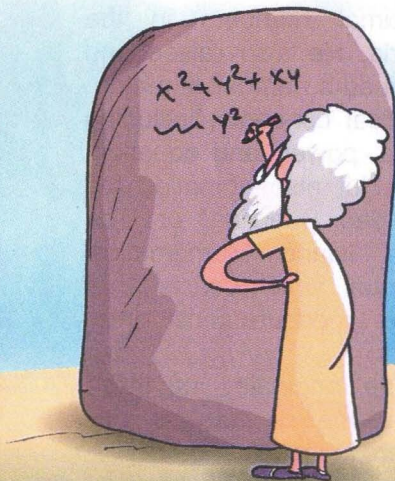
## Why is Liu Hui considered the greatest mathematician of Ancient China?

Liu Hui was a great Chinese mathematician who lived during the third century. He was most famous for his annotated text of 'Jiuzhang Suanshu' or 'The Nine Chapters on the Mathematical Art'.

The book consists of nine chapters containing 246 questions, with their solutions. Each of the nine chapters focuses on a separate part of daily mathematics. Liu Hui was the first person to put forward the concept of decimal numbers in the world. He also raised and defined a number of mathematical concepts, including area, power, and equation. Liu Hui also compiled the 'Haidao Suanjing' or 'The Sea Island Mathematical Manual' which consisted of nine measurement problems.

The originality of these problems impressed his peers in the West greatly.

## What is the role of Hypatia in the history of mathematics?

**H**ypatia, who was born in AD 351, was the first woman recognized as a mathematician and scientist since the recording of history. She became head of the Platonist school at Alexandria in AD 400.

Hypatia attracted many students since she was regarded as an authority figure. She is the first woman known to write on the subjects of mathematics, which included conic sections.

The early Egyptian mathematician, Diophantus, had his algebraic equations refined by Hypatia. She also wrote several papers on philosophy and astronomy. Only fragments of these writings remain.

Hypatia has been given credit for the astrolabe, which was used to measure star positions that were relative to the Earth. In AD 415, Hypatia was tortured to death by religious zealots.



*Hypatia*

## What are the contributions of Al-Khwarizmi?

$E$arly in the 9th century, there lived an outstanding Persian mathematician called Muhammad Al-Khwarizmi. He oversaw the translation of the major Greek and Indian mathematical and astronomical books, and produced original work which had a lasting influence on the advance on Persian, and later, European mathematics.



*Al-Khwarizmi*

The word 'algorithm' is derived from the Latinization of his name, and the word 'algebra' is derived from the Latinization of 'al-jabr', part of the title of his most famous book, in which he introduced the fundamental algebraic methods and techniques for solving equations. His most important contribution to mathematics was his strong advocacy of the Indian numerical system. The Indian numerals 1 - 9 and 0 - which have since become known as Indo-Arabic numerals - were soon adopted by the entire Islamic world.



Later, when Al- Khwarizmi's works were translated into Latin, they would be adopted throughout Europe as well.
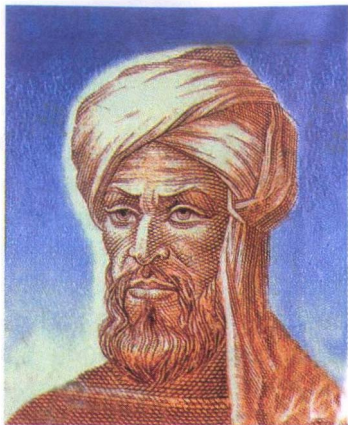
## What do we know about Ibrahim ibn Sinan?

Ibrahim ibn Sinan, mathematician and astronomer, was born in Baghdad in the year AD 908. He was a member of a family that had produced distinguished scientists since the time of his grandfather, Thabit ibn Qurra.

He wrote in his autobiography that he began his mathematical researches at the age of fifteen, and wrote a number of treatises by the time he was eighteen.

Ibrahim ibn Sinan was deeply interested in geometry, especially circles and their tangents. His mathematical works contain a number of powerful and novel investigations. These include a treatise on how to draw conic sections, useful for the construction of sundials.

Ibrahim ibn Sinan wrote many books including 'On Tangent Circles'; 'On Analysis and Synthesis'; 'Selected Problems'; 'Measurement of the Parabola'; and 'On Drawing the Three Sections'. His passion was the geometrical method of analysis and synthesis.

**STAR FACT**

### New Names

Besides the words 'Algebra' and 'Algorithm' Al-Khwarizmi's name is also considered as the root of the origin of other words as well. These include 'Guarismo', a Spanish word and 'Algarismo', a Portuguese word, both meaning 'digit'.

Your eye is out of range.
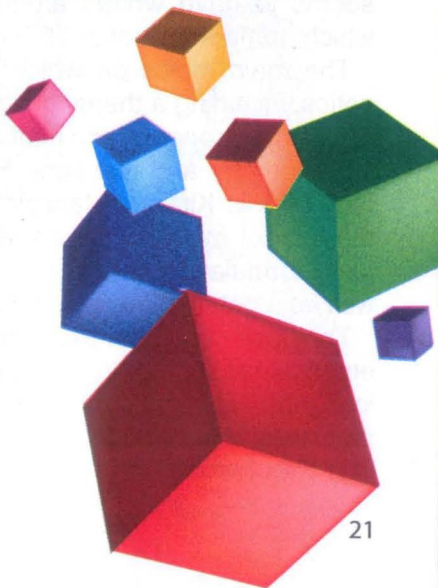
## Why is Abu al- Haytham considered to be a titan among mathematicians even today?

Abu al-Haytham, a famous mathematician, astronomer and philosopher, made significant contributions to the principles of optics, astronomy, mathematics and meteorology. He seems to have written around 92 works of which, remarkably, over 55 have survived.

The main topics on which he wrote were optics, including a theory of light and a theory of vision, astronomy, and mathematics, including geometry and numbers. His most important work is Kitab al-Manazir which contains the correct model of vision, and has a complete formulation of the laws of reflection as well as a detailed investigation of refraction.

The book combines experiments with mathematical reasoning. In the field of mathematics, Abu al-Haytham worked on Euclid's theorems. He replaced some indirect proofs with direct proofs.
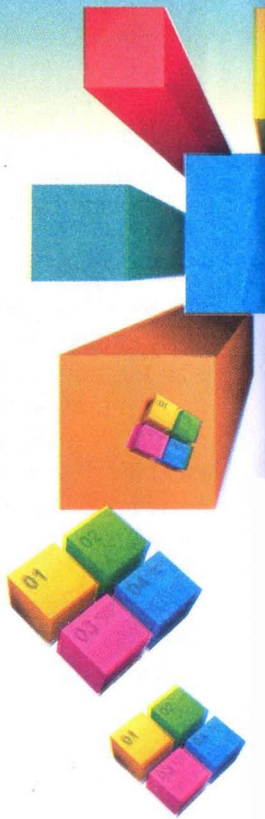
## What are the major contributions of Leonardo of Pisa?

Leonardo of Pisa, also known as Fibonacci, was an Italian mathematician, considered by some researchers to be perhaps the most gifted mathematician of the Middle Ages.

While travelling with his father to a trading post in northern Africa, Leonardo first learned the Indo-Arabic numerals. He recognized the ease and efficiency of the system, and saw that these numerals were far more workable than the Roman numeral system then in use in Italy.

Leonardo is best known for being instrumental in bringing the Indian and Arabic numeral systems to Europe. He introduced these systems through his book, 'Liber Abaci' or Book of Calculation.

He is also remembered for a number sequence named after him, the Fibonacci numbers. This is regarded as one of the greatest contributions of Fibonacci to mathematics. The Fibonacci number is the series of numbers starting with one -in Leonardo's calculation- or zero -in modern calculation- and adding the previous digit to itself to get the next number. Leonardo or Fibonacci even has an asteroid named after him- the 6765 Fibonacci!
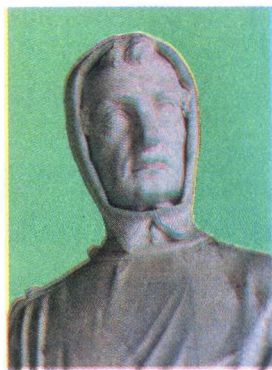


*Leonardo of Pisa*

Europe needs these numbers.

## Why is Muhammad ibn Hasan Tusi important in mathematics?

Muhammad ibn Hasan Tusi , better known as Nasir al-Din Tusi, was a mathematician, astronomer, philosopher, and theologian.

He created ingenious mathematical models for use in astronomy. Tusi was instrumental in building an observatory where he spent 12 years, and produced an accurate table of planetary movements. These tables remained popular among astronomers until the 1600s.

In mathematics, Tusi pioneered spherical trigonometry, and treated trigonometry as a new mathematical discipline. It was in the works of Tusi that trigonometry achieved the status of an independent branch of pure mathematics distinct from astronomy.

Tusi also developed six fundamental formulas for the solution of spherical right-angled triangles. He was without doubt, one of the greatest scholars of his time, and one of the most influential figures in Persian intellectual history.
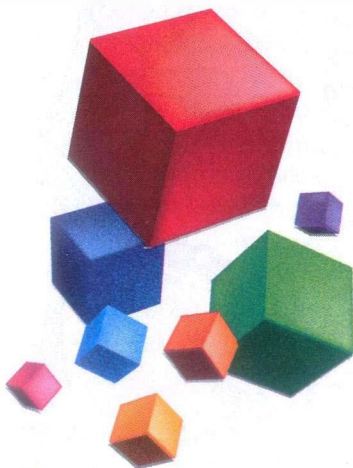
## Why is Qin Jiushao considered to be a great mathematician?

**Q**in Jiushao was a remarkable Chinese gentleman who did not devote his life to mathematics- yet is considered a great mathematician. He was actually a bureaucrat who interrupted his government career for three years, beginning in 1244, because of his mother's death.

During the mourning period, he wrote his only mathematical book, now known as Shushu Jiuzhang or 'Mathematical Treatise in Nine Sections'. This treatise covered a variety of topics in mathematics. In geometry, Qin Jiushao discovered a formula for finding the area of a triangle from the given lengths of three sides. He introduced the techniques for solving certain types of algebraic equations using a numerical algorithm.

Qin Jiushao was also the first to use the zero symbol into written Chinese mathematics.
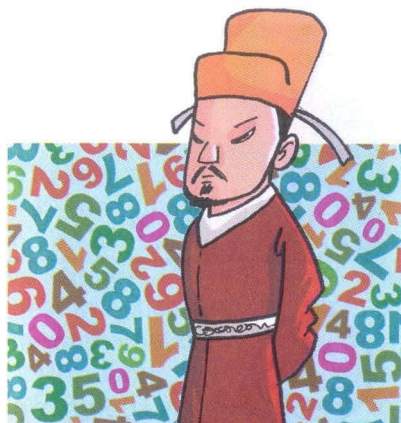
## Why does Yang Hui have an important place in the history of mathematics?

Yang Hui, who lived during the 13th century in China, was a contemporary of Qin Jiushao. He wrote several outstanding mathematical texts, and was well known for his ability to manipulate decimal fractions.

Yang Hui worked on magic squares, magic circles, and the binomial theorem. Magic squares are a square grid of numbers containing the numbers 1,2,3, and so on.

Each number appears only once- yet each row, column and diagonal add up to the same number! A magic circle is the arrangement of natural numbers on circles, where the sum of the numbers on each circle, and the sum of numbers on diameter, are identical.

Magic squares and magic circles are fascinating, yet Yang Hui is best known for his presentation of Yang Hui's Triangle, which is a special triangular arrangement of numbers used in many areas of mathematics.



*Yang Hui*

## STAR FACT

### Pretending Madness

Al-Haytham, the great mathematician, once boasted that he could regulate the floods of the Nile by applying his mathematical knowledge. However, when he was ordered by the ruler to do so, he quickly realized that it was an impossible task, so he pretended to be mad to save his life! It was only after the ruler died, that he could stop faking madness and apply himself to mathematics once again!

## Why was Kamal al Farisi remarkable among his contemporaries?

**K**amal al Farisi lived in the 13th century in Persia. He made two major contributions to science. The first was in the field of optics, and the second in mathematics.

His work on optics was prompted by a question put to him concerning the refraction of light. In the course of his studies, he was able to formulate a mathematically satisfactory explanation for the rainbow, and the nature of its colours.

Farisi made a number of important contributions to number theory. His most impressive work in number theory is on amicable numbers. An amicable or friendly number is the one which has a friendly pair.

Friendly pairs are such numbers which have the divisors adding up to the other number. Al Farisi is remarkable in that he introduced a major new approach to a whole area of number theory.
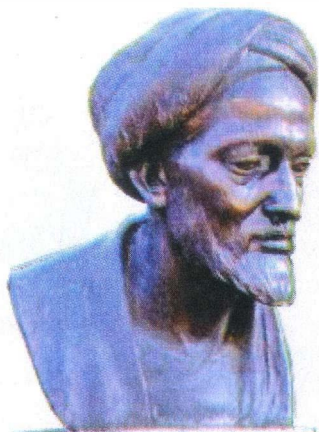


*Kamal al Farisi*
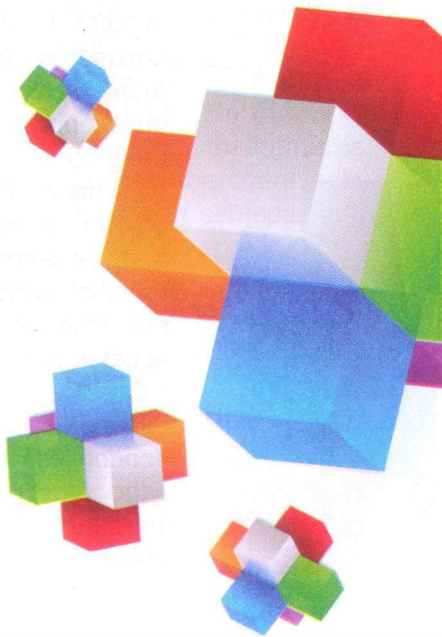
It's nothing but the graph of velocity.
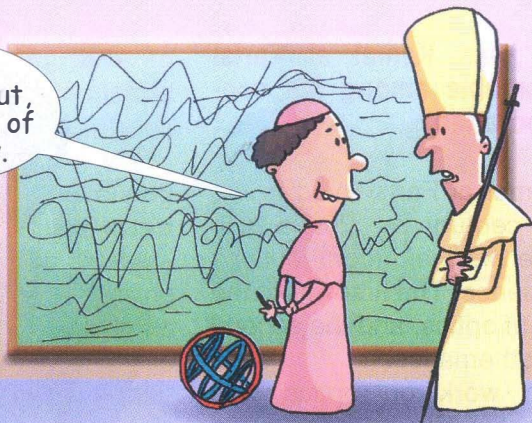
## What were the contributions of Nicole Oresme?

**N**icole Oresme was born in Northern France in 1323. As a young man, he studied theology, philosophy, and logic in Paris. He translated many of Aristotle's works. Like other medieval philosophers, Oresme was interested in measuring 'forms'.

Forms were an idea of Aristotle's- they included qualities like the velocity of a moving object, and the temperature at different places in a material. Oresme made a graph of velocity versus time for an object moving with constant acceleration, like a falling ball.

Oresme's book on 'Latitudes of Forms' was very popular. He also wrote influential works on economics, mathematics, physics, astrology, astronomy, philosophy, and theology. His most important contributions to mathematics was the notion that fractions that could not be expressed as powers of one another.

*Luca Pacioli*



## STAR FACT

### Maths and Magic

**L**uca Pacioli wrote a book that showed how mathematics is linked to magic. The book contains the first reference to card tricks as well as guidance on how to juggle, eat fire, and make coins dance!

## What do we know about Luca Pacioli?

**L**uca Pacioli was an Italian mathematician, born in 1445 in Sansepolcro, Tuscany. He greatly influenced the world he lived in with his writings. He moved to Venice around 1464, where he continued his own education, while working as a tutor to the three sons of a merchant. It was during this period that he wrote his first book— a treatise on arithmetic for the three boys he was tutoring.

Pacioli taught at various universities including the University of Naples and the University of Rome. He also taught mathematics to Leonardo da Vinci. He published several books on mathematics, including one on merchant arithmetic, dealing with subjects such as barter, exchange, profit, mixing metals, and algebra.

Pacioli was the initiator of the double entry accounting system which is almost the same as the accounting system used nowadays. He introduced the use of ledgers, journals and book-keeping, and was the first person to have used a balance sheet and income statement.

*Niccolo Fontana*



Hooray! Even I can't decode this.

## How has Niccolo Fontana Tartaglia contributed to mathematics?

In 1535, a young Venetian named Tartaglia first revealed a mathematical finding hitherto considered impossible. Tartaglia's greatest legacy to mathematical history occurred when he won the 1535 Bologna University mathematics competition, by demonstrating a general algebraic formula for solving cubic equations. In the highly competitive and cut-throat environment of 16th century Italy, Tartaglia even encoded his solution in the form of a poem in an attempt to make it more difficult for other mathematicians to steal it.

Niccolo Fontana published many books, including the first Italian translations of Archimedes and Euclid, and an acclaimed compilation of mathematics. He was the first to apply mathematics to the investigation of the paths of cannonballs, and this became known as the science of ballistics. His best known work is his treatise 'General Trattato di numeri, et misure' published in Venice in 1556–1560. Niccolo Fontana became known as Tartaglia -meaning 'the stammerer'- for a speech defect he suffered due to an injury he received in a battle.

## Advantage Gambling!

Cardano was addicted to gambling. It was his love of gambling that led him to formulate the elementary rules of probability, and made him one of the founders of this field.
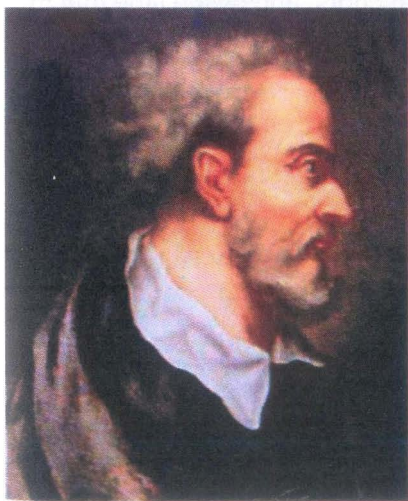


*Girolamo Cardano*

## What made Girolamo Cardano an outstanding mathematician?

Sixteenth century physician Girolamo Cardano was not only a prolific writer and mathematician, but also one of the most colourful figures of his era. He wrote more than 200 works on medicine, mathematics, physics, philosophy, religion, and music. In 1539, he published two books on arithmetic, embodying his popular lectures.

Cardano was the first mathematician to make systematic use of numbers less than zero. He published the first comprehensive solution for finding the roots of cubic equations. This led to a bitter feud with Niccolo Tartaglia, who accused Cardano of publishing results that were shown to him in confidence, on the condition that he would never reveal them. Cardano's book 'The Great Art,' or the 'Rules of Algebra,' is one of the cornerstones of the history of algebra.

## Why is Lodovico Ferrari considered to be a giant amongst mathematicians?

Lodovico Ferrari was an Italian mathematician famed for solving the quadratic equation. He had showed mathematical promise at a young age, and on November 30, 1536, fourteen-year, old Ferrari started working with the famous physician and mathematical genius, Cardano. Over time, Cardano was very impressed by Ferrari's intelligence, and soon began to teach him mathematics. Ferrari began to collaborate with Cardano on his manuscripts, and by the time that Ferrari was 18, he began to lecture on mathematics.

In 1540, Ferrari came up with the general solution for the quadratic equation. The biquadratic, or quartic, equation is an algebraic equation that contains the fourth power of the unknown quantity, but no higher power. Cardano would later publish this method in his famous book Ars Magna. In 1541, when Cardano resigned his post in mathematics in Milan, Ferrari, then 20, was able to succeed him. He soon established a reputation as one of Italy's top mathematicians, and held a series of very well paid positions till the time of his death.

Tell Me Why

The number eight- made simple.

2x2x2
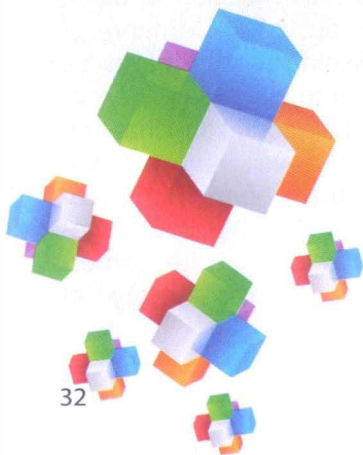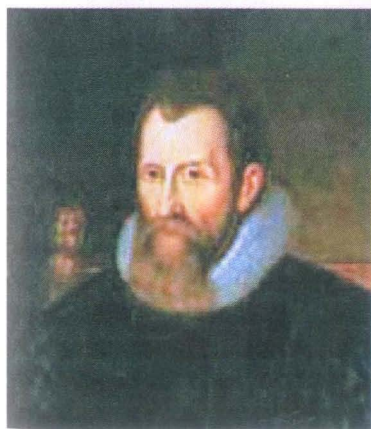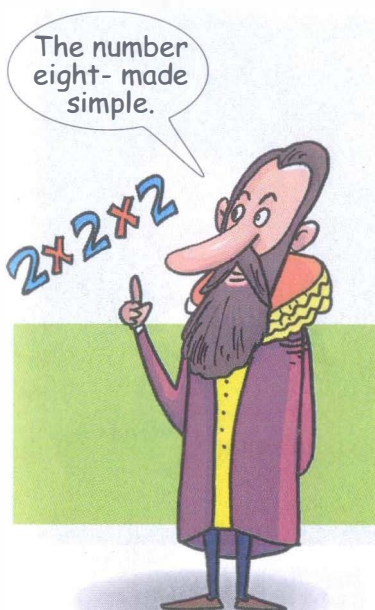


*John Napier*

## Why is John Napier an important figure in the history of mathematics?

John Napier is one of the superstars of mathematics. A distinguished Scottish mathematician and theological writer, John Napier is famously credited as the man who invented the concept of logarithm. In its simplest form, a logarithm answers the question as to how many times a number has to be multiplied, to get another number. For example, if you were asked how many times you have to multiply 2 to get 8, the answer would be 3 as 2X2X2= 8.

With his innovative discoveries and research, Napier created a storm in the field of mathematical calculations. Napier's other contributions were in the field of spherical trigonometry, the invention of the divining rods, and pressing forward the use of decimal fractions. It was due to his ground-breaking inventions that Napier earned the respect of some of the most illustrious astronomers and scientists of his era.

## Why is Rene Descartes considered one of the most gifted of mathematicians?

Rene Descartes was an eminent French mathematician, philosopher, and writer, who has been popularly referred to as 'father of modern philosophy'. Born in 1596, he made many important contributions to mathematics, including those in the fields of algebra and analytical geometry.

He invented the system of representing unknown factors in equations by x, y, and z, and known factors by a, b, and c. His works became the foundation for the development of the calculus theory.

European mathematicians had previously viewed geometry as a more fundamental form of mathematics, serving as the foundation of algebra. Rene Descartes, on the other hand, believed in the importance of algebra, and was the first one to assign a fundamental place for algebra.



*Rene Descartes*
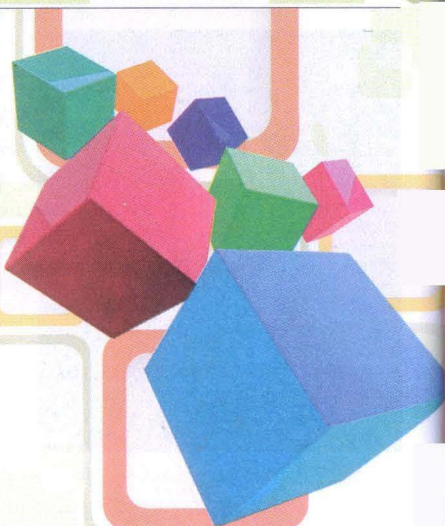
*Girard Desargues*

## Why is Girard Desargues a star in mathematics?

Girard Desargues was a French mathematician who lived in the 17th century. He had many interests, but his passion was geometry.

Desargues had contact with most of the leading French mathematicians of his day. He revised parts of the famous book 'Conics' written by Apollonius of Perga, and invented a new, non-Greek way of doing geometry, now called 'projective' or 'modern' geometry.

This new approach to geometry was greatly appreciated by his suc-

Don't break my vision.
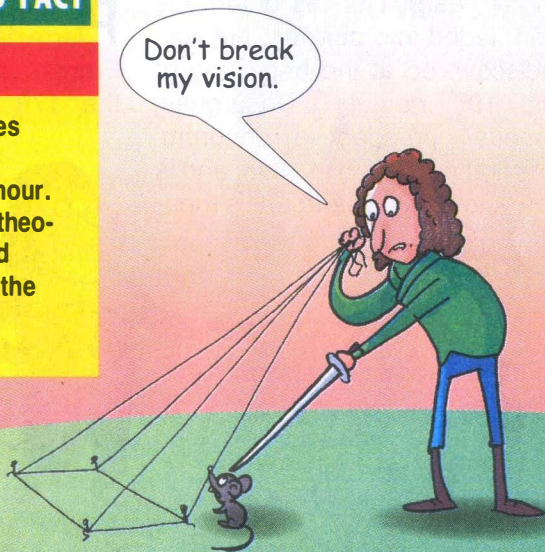
## What are the contributions of Bonaventura Cavalieri?

**B**onaventura Cavalieri was an Italian mathematician who lived in the 17th century.

In 1629, he became professor of mathematics at Bologna, where he continued to teach until his death.

Cavalieri was one of the leading mathematicians of

cessors. As a mathematician, Desargues was very good indeed, highly original and painstaking.

Fifty years after his death, his work faded into oblivion, but was rediscovered at the beginning of the 19th century. Desargues' famous 'perspective theorem' was first published in 1648, and is now known as Desargues's theorem.

## Why is Pierre de Fermat a legendary figure in mathematics?

**P**ierre de Fermat, a famous French mathematician of the 17th century, is often



Bonaventura Cavalieri

Look! That's my latest theorem!
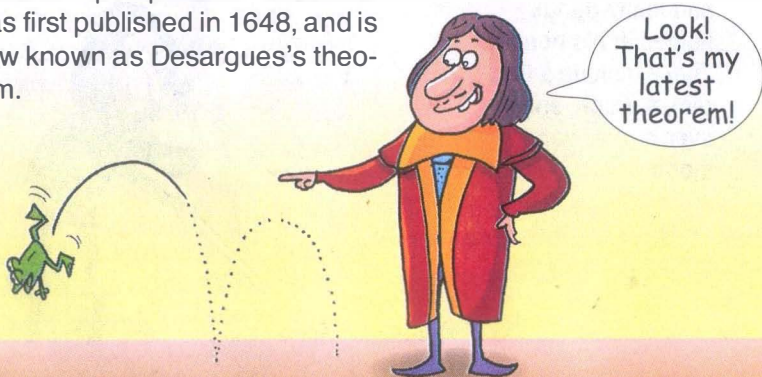
his time, and is celebrated for his 'Geometry of Continuous Indivisibles', to which he was led by his investigations on the determination of areas and volumes.

Cavalieri published an account of his method in 1635. In this book, he developed the theory of mirrors shaped into parabolas, hyperbolas, and ellipses, and various combinations of these mirrors.

Cavalieri's work proved to be a forerunner of integral calculus. He believed that lines are made up of an infinite number of points, surfaces of an infinite number of lines, and solids of an infinite number of surfaces.

Cavalieri also gave the first demonstration of a theorem known as the theorem of Pappus, and did much to render common the use of logarithms in Italy.

called the founder of the modern theory of numbers.

He discovered the fundamental principles of analytical geometry. He also conceived the idea of differential calculus, and the cofounder, along with Pascal, of the theory of probability.

Fermat contributed to the development of calculus through his work on the properties of curves. His views on the fundamental principles of probability became the foundation of the probability theory, and grew into the theory of numbers.

Fermat had a strong interest in the field of optics. He deduced the laws of refraction and reflection,
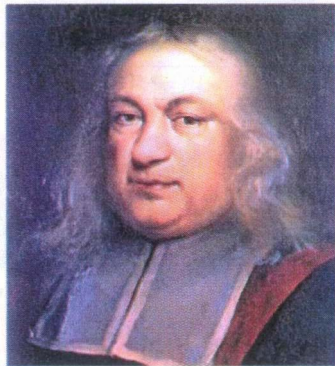


*Pierre de Fermat*

and formulated the principle known as Fermat's Principle.

Fermat was a lawyer by profession.

*John Wallis*



## What are the contributions of John Wallis to mathematics?

John Wallis was born in 1616, and was educated at Felsted School.

One day, when he was fifteen years old, he happened to see a book of arithmetic in his brother's hands. He was curious about the odd signs and symbols in it, and so, he borrowed the book.

In a fortnight, with his brother's help, he had mastered the subject! Wallis made many contributions to different branches of mathematics including trigonometry, geometry, and calculus. He is also credited for creating the symbol for infinity.

In addition, he is generally credited as the originator of the idea of the number line, where numbers are represented geometrically in a line, with the negative numbers represented by lengths opposite in direction to lengths of positive numbers. John Wallis wrote many books including 'Opera Mathematica' and 'Institutio Logicae'.
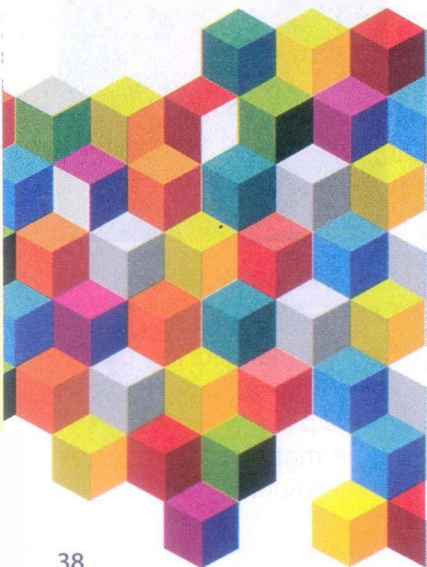
## Why did Blaise Pascal tower among his contemporaries?

**B**laise Pascal was a French mathematician, physicist, and religious philosopher, who laid the foundation for the modern theory of probabilities.

He was born on June 19th, 1623, in Clermont-Ferrand, France. Blaise was an inquisitive boy, who at the age of 12, began exploring geometry on his own. He even made up his own terminology, not having learned the official terms. The prodigy quickly managed to
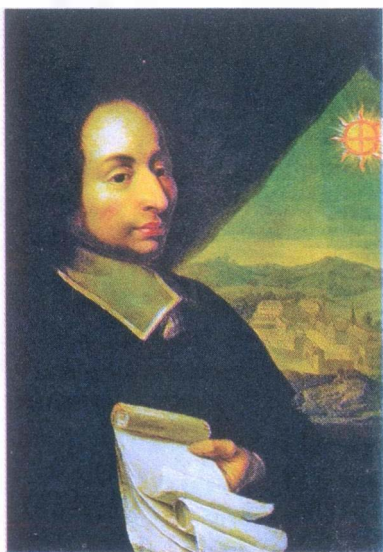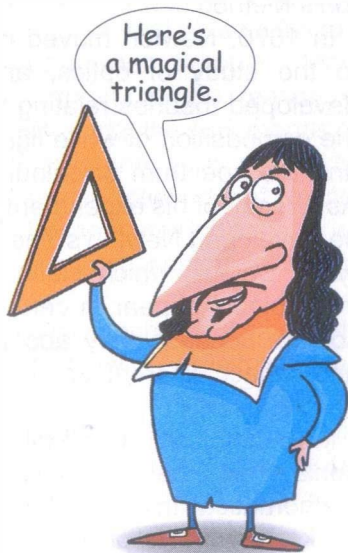


*Blaise Pascal*

work out that the sum of a triangle's angles are equal to two right angles. At the age of 16, Blaise presented a number of his early theorems, including his 'mystical hexagon'.

In 1642, he invented the Pascaline, an early calculator. Blaise's 'Essay on Conic Sections' marked an important leap in projective geometry, which involved transferring a 3-D object onto a 2-D field. Pascal laid the foundation of the probability theory.
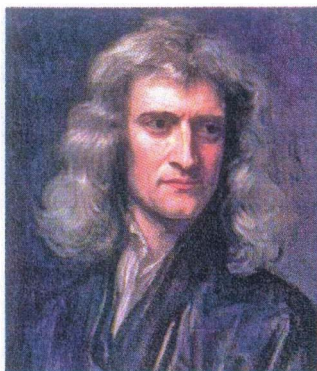


Here's a magical triangle.

*Sir Isaac Newton*

## What are the contributions of Sir Isaac Newton?

**S**ir Isaac Newton, an Englishman, was influenced by the writings of Galileo, Nicholas Copernicus, and Johannes Kepler.

By 1665, Newton began developing a mathematical theory that would lead to the development of calculus, one of the fundamental branches of mathematics. Newton would go on to discover other important maths theories such as Newton's Identities, and Newton's Method.

In 1670, Newton moved on to the study of optics, and developed theories relating to the composition of white light, and the spectrum of colours. As a result of his experiments, he developed Newton's Theory of Colour, which claimed that objects appear in certain colours because they absorb and reflect different amounts of light.

In 1687, he published 'Philosophiae Naturalis Principia Mathematica'. In this landmark work, Newton explained his
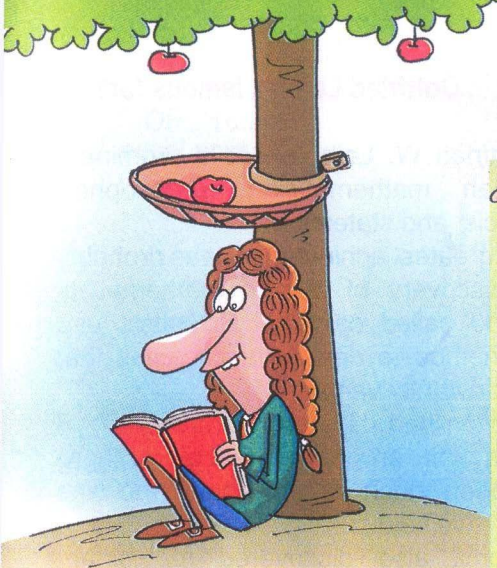
**Hair for Sure**

Newton became rather eccentric in his later life. It is now believed that this was the result of mercury poisoning. An analysis of his hair after his death showed high levels of mercury, probably acquired as a result of his experiments with mercury.

three laws of motion, which included his theory on gravity.

According to Newton, gravity is the reason that objects fall to the ground when dropped. Moreover, gravity is the reason why planets orbit the sun, moons orbit planets, and why ocean tides exist. It is believed that Newton's ideas concerning gravity were inspired by apples falling from trees.

Following the publication of his work, Newton became instantly famous throughout Europe, and to this day, his contributions to mathematics and science have made him one of the all-time greats in these fields.
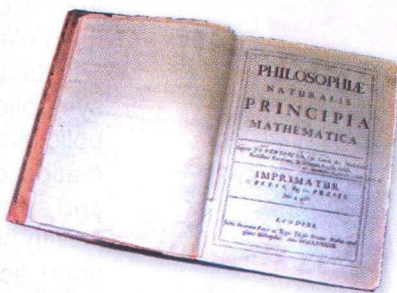


*Philosophiae Naturalis Principia Mathematica*

*Gottfried Leibniz*



## What is Gottfried Leibniz famous for?

**G**ottfried W. Leibniz was a prominent German mathematician, philosopher, physicist and statesman.

His greatest achievement was probably the discovery of a new mathematical method called calculus. Scientists use this method to deal with quantities that are constantly varying.

Newton had devised a similar method for his work on gravity. Therefore, there has been much debate about who was first in this field.

Leibniz also discovered the binary number system, and he invented the first calculating machine that could add, subtract, multiply and divide.

The binary system has only two numbers- 0 and 1. The number system that we normally use is the decimal number system. It has 10 numbers moving up from 0 to 9. Binary numbers are very useful in electronics and computer systems.

Leibniz is often known as the founder of symbolic logic as he developed a symbolic language in which any item of information can be represented in a natural and systematic way.

With his death in 1716, the world lost a great scientist who knew almost everything that could be known at the time about any subject or intellectual enterprise.

**Tell Me Why**
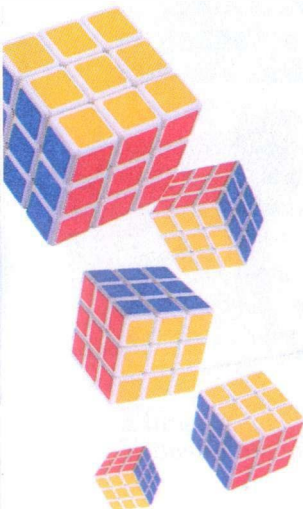
Oh... four equal parts....



*Jacob Bernoulli*

## Why is Jacob Bernoulli one of the most respected names in mathematics?

**J**acob Bernoulli was a well known Swiss mathematician whose well-researched concepts brought about a revolution in Swiss mathematics.

From 1676 to 1682, Jacob travelled all around Europe, learning about the latest discoveries made by scientists in the field of mathematics and astronomy. These travel expeditions not only widened Jacob's knowledge, but also laid the foundation for Jacob's association with numerous mathematicians which he continued until late in his life.

Jacob Bernoulli's foremost significant contributions to mathematics were noted in the pamphlets which accounted for information on the parallels of logic and algebra, and his work on probability.

These were published in the year 1685. Two years later, Bernoulli's work on geometry was published, which gave a method to divide any triangle into four equal parts, with two perpendicular lines.

*Plaque on
Jacob Bernoulli's tomb*

In 1689, Jacob Bernoulli published an important work on infinite series, and his law of large numbers in probability theory.

From 1682 to 1704, Jacob Bernoulli published five treatises on infinite series. His most important contribution was in the field of probability, where he derived the first version of the law of large numbers in his work 'Ars Conjectandi'.

## CURIOUS FACT

### Probability

Jacob Bernoulli died before he could finish 'Ars Conjectandi.' It was published eight years after his death, and in spite of being incomplete, it remains his greatest work.

## What are the contributions of Brook Taylor?

**B**rook Taylor was an Englishman who was interested in art and music, but his first love was mathematics.

He displayed exceptional abilities in mathematics by writing a very important paper even before his graduation. He wrote two very significant books 'Methodus Incrementorum Directa et Inversa' and 'Linear Perspective' which were published in 1715.

Taylor had thirteen published articles on various topics such as capillary action, thermometers, and magnetism. He added a new branch in mathematics known as the 'Calculus of Finite Differences'. He was the one to invent 'Integration by Parts' and also a series called the 'Taylor's Expansion'. He is also famous for 'Taylor's Theorem' which has played a fundamental role in the evolution of mathematics.

Brook Taylor, the great mathematician, died on 30th November 1731, made many important contributions to the world of mathematics.



*Brook Taylor*
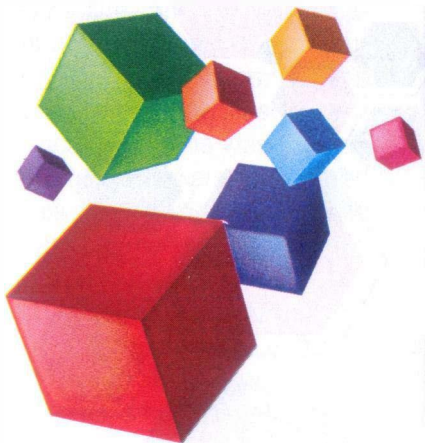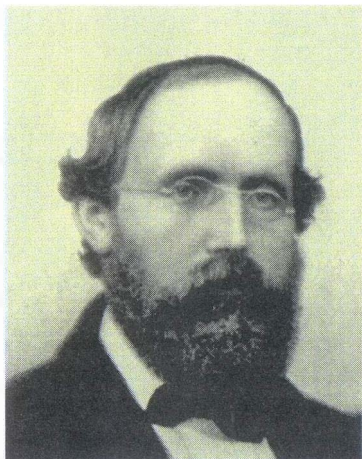
*Christian Goldbach*



## What do we know about Christian Goldbach?

Christian Goldbach, born in 1690, was a Prussian amateur mathematician and historian who lived in St Petersburg and Moscow.

As a mathematician, he researched theorems on perfect powers, and wrote various papers in support of his mathematical theories and findings.

His main claim to fame, and the reason that he is remembered today, is because of the Goldbach Conjectures. One conjecture states that every even number can be expressed as a sum of two prime numbers, including 1 as a prime number, if needed.

It also proposed that every odd number can be expressed as a sum of three prime numbers. Goldbach communicated with several famous mathematicians including Gottfried Leibniz and Nicholas Bernoulli. He was known to correspond with these mathematicians, and especially with Leonhard Euler, with whom Goldbach chose to discuss the Goldbach's Conjecture in detail.

## Uncle Petros

In 1992, the Greek author Apostolos Doxiadis wrote 'Uncle Petros and Goldbach's Conjecture'. It is an unusual novel about mathematical problems and the history of mathematics.
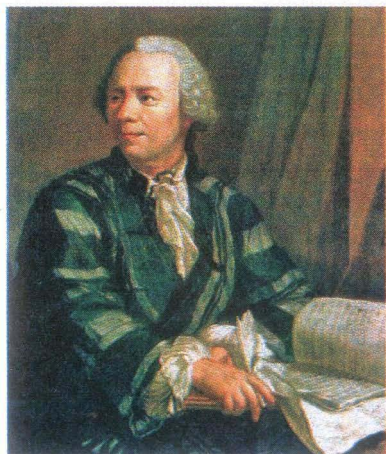


*Leonhard Euler*

## Why is Leonhard Euler an important figure in the history of mathematics?

Born in 1707, Swiss mathematician and physicist Leonhard Euler is famous for his contributions to a wide range of fields, including the introduction of modern mathematical notation.

Euler published several articles during this time, and his book 'Mechanica', earned him worldwide fame as a prominent mathematician.

Euler made groundbreaking contributions to analytic geometry, trigonometry, calculus and number theory. Euler's constant, Euler's equations, Euler's line, and Euler's variables are some of his contributions to mathematics. Euler's application of calculus to geometrical problems was the first of its kind. He is also renowned for his work in mechanics, fluid dynamics, optics, astronomy, and music theory.

Euler published about 886 books and papers, and still remains the most prolific writer of mathematics in history.

## Why is Joseph Lagrange a super star of mathematics?

Joseph Louis Lagrange was an Italian mathematician and astronomer. The greatest mathematician of the eighteenth century, he was self-taught.

Lagrange is best remembered for his contribution to the metric system, and his addition of the decimal base. He made some important discoveries which would contribute substantially to the new subject of the calculus of variations.



*Joseph Louis Lagrange*

Lagrange worked at Berlin for 20 years, producing numerous top quality papers, and regularly winning the prize from the Académie des Sciences of Paris. His work in Berlin covered many topics like, astronomy, the stability of the solar system, mechanics, dynamics, fluid mechanics, probability, and the foundations of the calculus. He also worked on number theory, proving in 1770, that every positive integer is the sum of four squares. Integers are sets of whole numbers and their opposites-but not fractions.

Lagrange is also known for a great deal of work on planetary motion, which is why he is referred to as an astronomer- mathematician.
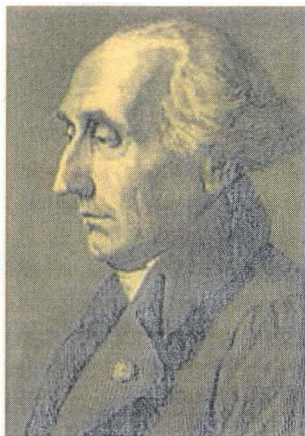
## Why is Gaspard Monge famous?

**B**orn in 1746, French mathematician Gaspard Monge is famous for inventing descriptive geometry.

Descriptive geometry is the study of the mathematical principles of representing three-dimensional objects in a two-dimensional plane and the mathematical basis for technical drawings.

Monge gained early fame by devising a plan for gun emplacements for a fortress. He substituted a certain geometrical process for the calculations that avoided the unwieldy techniques used at the time.

Monge did enormous work in geometry and mechanics, including fortifications to scaffolding and architecture in general. In pure mathematics, he may be regarded as the father of differential geometry.

Monge was one of the initiators of the metric system in France, and by 1789, had achieved the status of one of the best among French scientists.
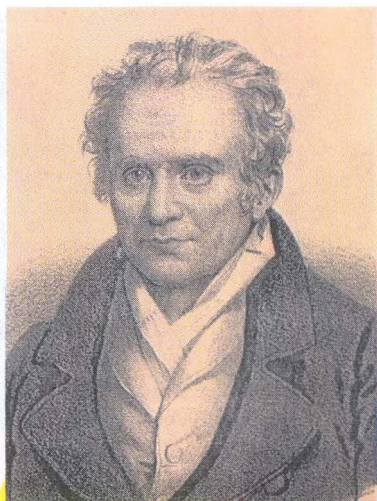


*Gaspard Monge*

*Pierre-Simon Laplace*

## Why is Pierre-Simon Laplace referred to as the Newton of France?

**B**orn in 1749, French astronomer and mathematician Pierre-Simon Laplace is famous for Laplace's equation, and also for his important contributions to mathematical astronomy and statistics.

Pierre-Simon Laplace is highly regarded for his influential five-volume treatise 'Traite de Mecanique Celeste' or 'Celestial Mechanics,' which developed a strong mathematical understanding of the motion of the heavenly bodies. He made crucial contributions in the arena of planetary motion by applying Sir Isaac Newton's theory of gravitation to the entire solar system.

Laplace contributed heavily to the development of differential equations, difference equations, probability and statistics. His work regarding the theory of probability

*Adrien-Marie Legendre*

**F**rench mathematician Adrien-Marie Legendre was the founder of the theory of elliptic functions.

Born in 1752, he also made many contributions to several other fields, including number theory. He served as professor of mathematics at the Ecole Militaire, Paris, from 1775 to 1780, and in 1795, became a professor at the École Normale.

Legendre's work on elliptic integrals provided the basic analytic tools for mathematical physics. He also contributed to the theory of numbers, and the method of least squares.

Well-known and important concepts such as the Legendre polynomials and Legendre transformation are named after him. Most of Legendre's works were the source of inspiration for later mathematicians, and triggered several new mathematical theories.

and statistics is considered pioneering, and has influenced a whole new generation of mathematicians. Various fundamental concepts in mathematics- for instance, the Laplace operator in potential theory, and the Laplace transform in the study of differential equations- are named after him. He is sometimes referred to as the French Newton, or Newton of France, as he possessed a phenomenal natural mathematical intelligence, superior to that of any of his peers.

## What is Joseph Fourier famous for?

Joseph Fourier was a French mathematician and physicist who was very active during the French Revolution.

Later, Napoleon was impressed by his genius, and made him a baron. He accompanied Napoleon to Egypt, and became quite an Egyptologist too.

Fourier is famous for showing how the conduction of heat in solid bodies could be analyzed in terms of infinite mathematical series which is called the 'Fourier Series'. His scientific writings are contained in two volumes that were published in 1822.

His work continues to be extremely important in many areas of mathematics, and has been developed to create a whole new branch of mathematical analysis. Sunspots, tides, and even aspects of the weather can be explained by applying his work.



*Joseph Fourier*

## Why is Andre Marie Ampere one of the immortals of mathematics?

The 19th century French physicist and mathematician, Andre Marie Ampère is mainly credited for laying down the basis of electrodynamics, now known as electromagnetism.

At a very young age, he began to develop his own mathematical ideas, and also started to write a thesis on conic sections.

Later, he performed a series of experiments to clarify the exact nature of the relationship between electric current-flow and magnetism, as well as the relationships governing the behaviour of electric currents in various types of conductors.

On the basis of these experiments, Ampere formulated his famous law of electromagnetism known as Ampere's Law. This law is a mathematical description of the magnetic force between two electrical currents.

Ampere was the first person to demonstrate that a magnetic field is generated when two parallel wires are charged with electricity. This has made him one of the immortals of mathematics.



*Andre Marie Ampere*

**CURIOUS FACT**

### Ampere

When you study about electricity, you will learn that the unit of measurement of an electric current is called an ampere. It is named after the French mathematician, Andre Marie Ampere.

## Why is Carl Gauss an important figure in the history of mathematics?

**C**arl Friedrich Gauss is considered to be the greatest German mathematician of the nineteenth century.

His discoveries and writings influenced, and left a lasting mark in the areas of number theory, astronomy, geodesy, and physics, particularly the study of electromagnetism.

Gauss pursued his studies at the University of Gottingen. While there, he submitted a proof that every algebraic equation has at least one root or solution. This theorem had challenged mathematicians for centuries, and is called 'the fundamental theorem of algebra'.

Gauss' next discovery was in a totally different area of mathematics. In 1801, astronomers had discovered what they thought was a planet, which they named Ceres. They eventually lost sight of Ceres, but their observations were communicated to Gauss. He then calculated its exact position, so that it was easily rediscovered. He also worked on a new method for determining the orbits of new asteroids.

Gauss published over 150 works in his lifetime, and was referred to as 'the prince of mathematicians'.



*Carl Friedrich Gauss*

Back to 'roots'.
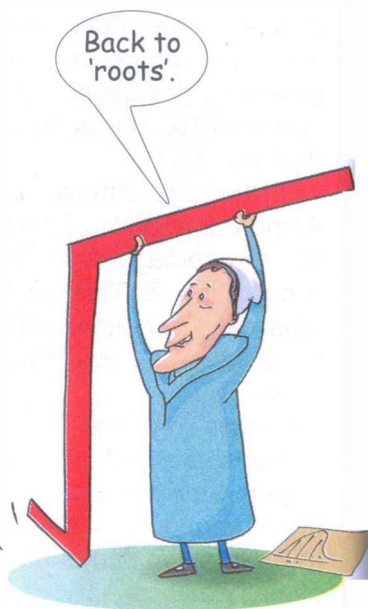
## What are the contributions of Augustin Louis Cauchy?

Augustin Louis Cauchy, born in 1789, was a French mathematician. He was famous for the countless contributions he made to the field of mathematics.

Several areas where he made his presence known are complex functions, optics, elasticity, group theory, mathematical physics, astronomy, hydrodynamics, and differential equations.

In fact, there are sixteen concepts and theorems named after him- more than any other mathematician. Cauchy was exposed to famous scientists as a child, and began his mathematical career in 1811. Over a period of fifteen years, from 1815 to 1830, Cauchy's name grew with distinction as he was appointed adjoint professor and full professor at École Polytechnique, and to chairs at the Faculte des Sciences and the Collège de France. His famous textbooks, which date from this period, display exactness unheard of until then, and contain his fundamental works in analysis, which have been translated several times.
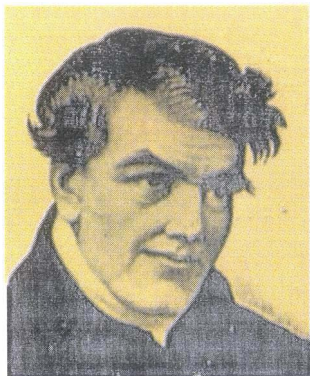
**STAR FACT**

### Bessel

Friedrich Bessel, born in 1784, was a German astronomer and mathematician. He worked on the 'Theory of Functions' which has wide applications. This theory is named after him.
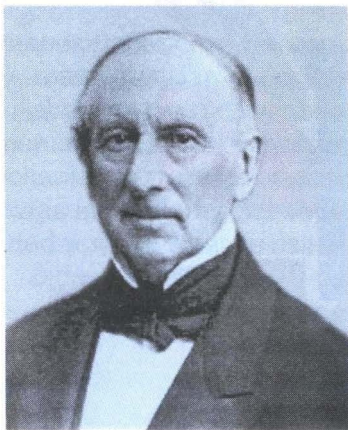
*Augustin Louis Cauchy*

*George Peacock*

## Why are George Peacock's contributions to mathematics remarkable?

George Peacock was a 19th century Scottish mathematician. In 1815, he, along with Charles Babbage, formed the Analytical Society.

At that time, the greatest works on mathematics, existed in the French language.

One of the first tasks of the society was to translate from the French the smaller work of Lacroix on the differential and integral calculus. This was followed by translations of other important works. In a series of papers read to the Cambridge Philosophical Society through the 1820s, George Peacock laid the foundation for a natural history of arithmetic that would tell a story of human progress from counting, to modern arithmetic.

According to him, the science of counting would suggest arithmetic, arithmetic would suggest arithmetical algebra, and, finally, arithmetical algebra would suggest symbolic algebra. In 1830, he published 'A Treatise on Algebra' with the aim of placing algebra on a true scientific basis. It is largely for these contributions that Peacock is remembered to this day.
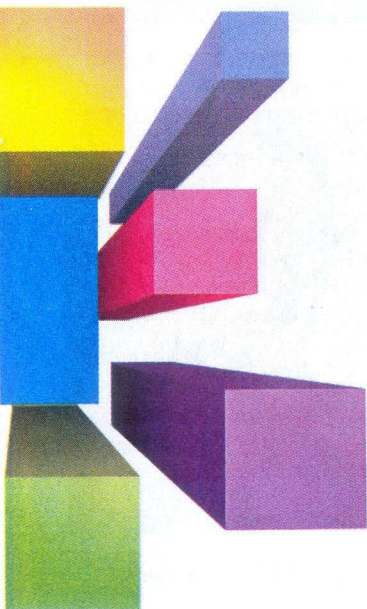
*Part of Babbage's Difference Engine*
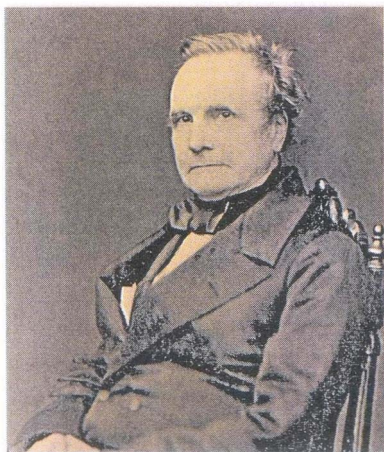


*Charles Babbage*

## Why is Charles Babbage considered one of the pioneers of computers?

Charles Babbage, a 19th century mathematician, was an Englishman whom the world remembers as the father of mechanical computers.

It was in 1820 that Babbage started work on what he called his 'Difference Engine'. This was a six wheeled machine which could perform mathematical calculations.

Babbage then went on to develop a bigger, better, machine named, Difference Engine 2.

*The Analytical Engine*
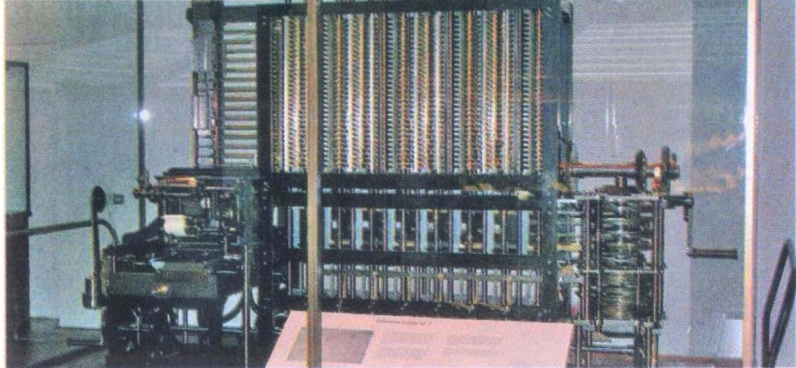
However, it was Babbage's Analytical Engine, a revolutionary device, on which his fame as a computer pioneer now largely rests.

This machine was intended to be able to perform any arithmetical calculation using punched cards that would deliver the instructions, as well as a memory unit, to store numbers and many other fundamental components of today's computers.

A program for the Analytical Engine was developed by a remarkable British mathematician Ada Lovelace. While Babbage's machines were mechanical and bulky, they had a basic design that is similar to the modern computer. It is for this reason why Charles Babbage is often looked upon as one of the pioneers of modern computers.

The engine is ready for analysis.

*Lobachevsky*

## What are the contributions of Nikolai Ivanovich Lobachevsky?

Lobachevsky, born in 1792, was a Russian mathematician who is known for establishing a branch of geometry called Lobachevskian geometry.

His idea was first reported on February 23rd, 1826, and he wrote a paper about it titled 'A Concise Outline of the Foundations of Geometry'. Lobachevsky's greatest work 'Geometriya' was completed in 1823. He also wrote 'New Foundations of Geometry'. Lobachevsky made many other contributions to mathematics. He was well respected for the work he developed with the theory of infinite series, especially the trigonometric series, integral calculus, and probability.

In 1834, he found a method for approximating the roots of an algebraic equation. In Russia, this method is called Lobachevsky method. Lobachevsky died at the age of 64, without realizing the fame and importance that his work would achieve.

*Janos Bolyai*



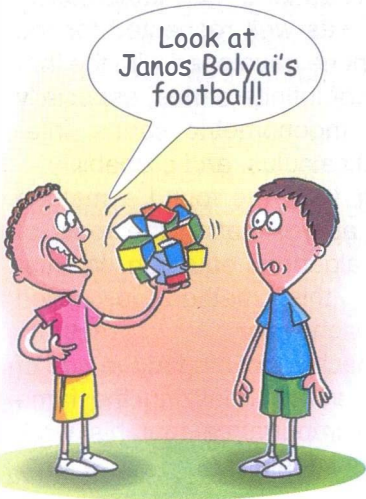Look at Janos Bolyai's football!
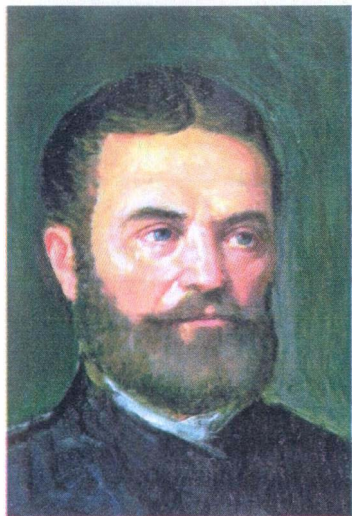
## What is the importance of Janos Bolyai in the history of mathematics?

Janos Bolyai, a Hungarian mathematician, was one of the founders of non- Euclidian geometry.

Euclidian geometry is the study of flat space based on the assumptions of the Ancient Greek mathematician, Euclid. Non Euclidian geometry differs from Euclidian geometry in its definition of parallel lines and is not based on Euclid's work. Bolyai developed a general geometry -or 'Absolute Geometry' in his words- which would contain Euclidean geometry as a special case.

In 1831, he published 'Appendix Scientiam Spatii Absolute Veram Exhibens' or 'Appendix Explaining the Absolutely True Science of Space', a complete and consistent system of non-Euclidean geometry.

When he died of pneumonia at the age of 57, he left behind tens of thousands of pages of mathematical writings. A crater on the Moon is named after this great mathematician who did not get the recognition he deserved during his lifetime.

*Carl Jacobi*

## What were the achievements of Carl Jacobi?

Carl Jacobi was born in Germany, and was a child prodigy. He studied philosophy, philology, and mathematics at the University of Berlin, and in 1825, became a lecturer in mathematics.

He later became a professor of mathematics in the University of Konigsberg. His career was also helped by the famous mathematician Friedrich Gauss. Jacobi's greatest contribution to mathematics was in elliptical functions.

An elliptical function is a function that is defined on a complex plain and that is periodic in two directions. His second greatest contribution to mathematics was in differential equations and rational mechanics, especially the Hamilton-Jacobi Theory.

In addition to these achievements, Jacobi's contributions remain a significant part of mathematics classes today all over the world.
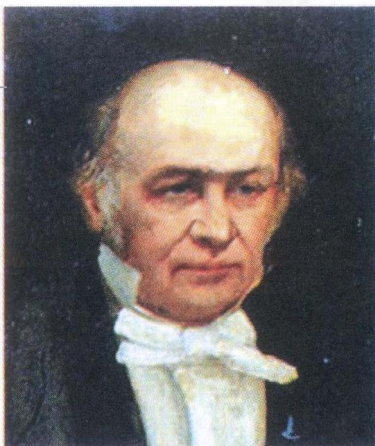
## Why is William Hamilton unique among his contemporaries?

One of the most significant Irish scientists, William Rowan Hamilton made noteworthy contributions in the field of classical mechanics, algebra, and optics.

In 1827, Hamilton presented a theory of a single function, now known as Hamilton's principal function. The theory brought together mechanics, optics and mathematics, thus helping establish the wave theory of light.

Hamilton also put forward the concept of 'Varying Action'. According to this theory, a single ray of light entering a biaxial crystal at a certain angle emerged as a hollow cone of rays.

This breakthrough is still known by its original name, 'conical refraction'. In dynamics, he introduced Hamilton's equations- a set of equations dealing with the positions and momentum of a collection of particles.

His most famous theory was the theory of 'quarternions', which was the forerunner of the vector theory.

Hamilton's work paved way to the modern study of classical field theories such as electromagnetism, and to the development of quantum mechanics.

## Why is Evariste Galois a key figure in the history of mathematics?

A 19th century French mathematician, Evariste Galois' work laid the foundations for two major branches of abstract algebra.

When he was just 16 years old, he published a paper on algebraic equations that made him famous. His paper on continued fractions was published in 1828, followed by significant discoveries in polynomial equation theory. Galois was very involved with the French Revolution, and was arrested twice.

This brilliant mathematician was only twenty years old at the time of his death. Though Galois did not live for long, his contributions to mathematics cannot be denied. He was the first to use the word 'group' in mathematics. He also developed the concept of normal subgroups and finite fields, known as Galois Fields. His most influential contribution to the field is the Galois Theory.



*Evariste Galois*

After solving this problem, I have some other problems to finish up.
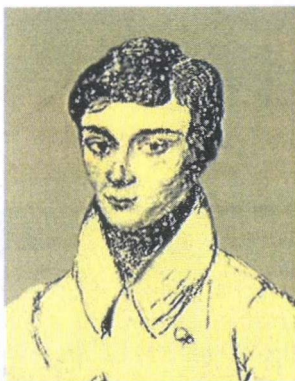
## What was the role played by Ada Lovelace in mathematics?

Ada Lovelace was a brilliant 19th century English mathematician who is considered to be the first computer programmer.

At 17, Lovelace became friends with Babbage, a professor of mathematics at Cambridge University, and became interested in his idea of designing a computing device. In 1843, Lovelace added details to an article describing the machine. She included step-by-step instructions on how the machine would work.

Lovelace's notes on Babbage's machine have been recognized as the first algorithm intended to be carried out by a machine. Because of this, she is often described as the world's first computer programmer.

While Babbage saw the machine as a calculator, Lovelace envisioned a machine that could use symbols and rules to compute and today, her vision has become a reality.

*Ada Lovelace*

## Why is George Boole considered a mathematical genius?

George Boole, a British mathematician, became interested in mathematics as a tool to solve mechanical problems in instrument making.

He was self educated in this field, and in 1838, he wrote his first mathematical paper. In 1841, he founded a new branch of mathematics called Invariant Theory that later inspired Einstein.

Boole won the first Gold Medal awarded by The Royal Society of London in 1844, for a paper on Differential Equations. But the work that stamped Boole as a mathematical genius was his contribution to mathematical logic and probability.
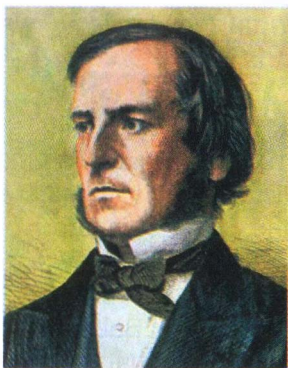


*George Boole*

Boole proposed that logical propositions should be expressed as algebraic equations.

With this concept, he had discovered a new kind of mathematics, which would later on prove ideal for the manipulation of information within computers.

In fact, much of the 'new math' studied in schools today is based on Boole's work.

That's a star ... Yes... No... Yes... No... No... Yes...

*Bernhard Riemann*



> This is the most complicated problem.
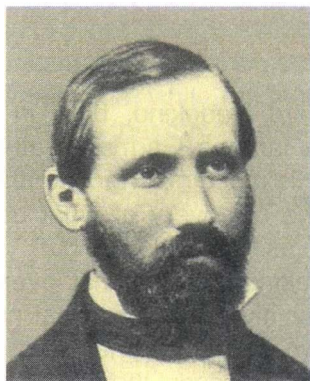
## Why does Bernhard Riemann stand out among his peers?

**B**ernhard Riemann was a 19th century German mathematician who made important contributions in the fields of analysis and number theory.

Riemann was interested in range of geometries different from Euclid's, and searched to develop a system of geometry that didn't deal with points, lines or shapes in the way they are normally thought about.

Riemann believed that it is impossible to construct a truly parallel line – it will always intersect with the original line.

Riemann also believed in taking all laws governing points and transforming them to the 'plenum', which means continuously filled space – essentially predicting dimensions higher than three or four. This is now called Riemannian geometry.

Apparently, Riemann's thinking about curved space influenced Albert Einstein's theory of relativity later on.
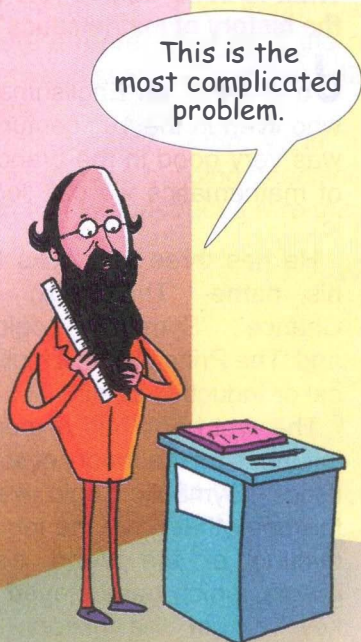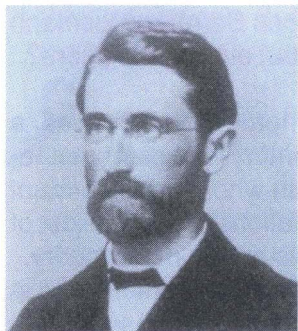
## Why is Richard Dedekind famous in the history of mathematics?

Richard Dedekind, born in 1831, was a famous German mathematician. His most important contribution was the discovery of what became known as the 'Dedekind cut'.

Dedekind realized that every real number divides the rational number into two subsects- one greater, and the other lesser than the rational


*Richard Dedekind*


AMAZING

### Bowling Machine

The bowling machine invented by John Venn was extremely accurate, and so good, that when the Australian cricket team was visiting England, the bowling machine was used against them for practice. Amazingly, the machine bowled out one of Australia's top players four times in succession!

## What is John Venn's role in the history of mathematics?

John Venn, an Englishman who lived in the 19th century, was very good in the branch of mathematics we call 'logic'.

He has three textbooks to his name- 'The Logic of Chance', 'Symbolic Logic,' and 'The Principles of Empirical or Inductive Logic.'

The first book had a great influence on the theory of statistics. 'Symbolic Logic' was the book that gave the introduction of the Venn diagrams, which have played a key role in the history of

number. To put it very simply, real numbers are the type of numbers that we normally use, while rational numbers are those that can be expressed as fractions.

Dedekind's brilliant idea was to represent the real numbers by such divisions of the rationals. He presented his findings in a book published in 1872. In another book about what are numbers, and what should they be, he put forward the definition of an infinite set, and analysis of number theory.
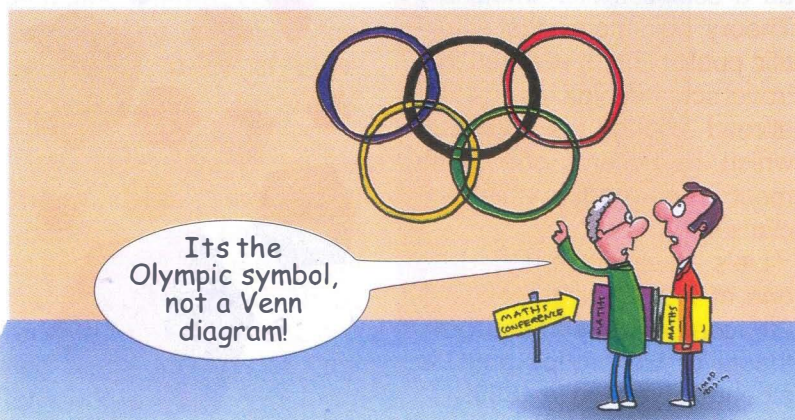
Along with working on mathematics, Dedekind pursued a teaching career too. He died in 1916.
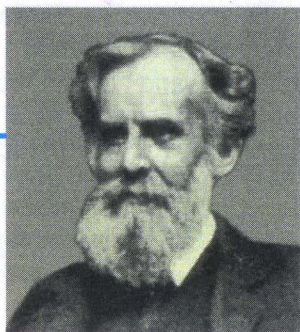


*John Venn*

mathematics. The Venn diagrams were a representation of the relation between sets, using circles within circles.

Interestingly, John Venn had an aptitude for building machines that led him to construct a rare machine.

### What made Marius Sophus Lie an outstanding mathematician?

Marius Sophus Lie was a Norwegian mathematician whose theories are indispensable tools for understanding the physical laws of nature.

Lie started to read geometry, starting with Euclid's 'Elements', and continued with books describing a 'new geometry'. Non-Euclidean geometry was still in its infancy, and in the years to come, Lie contributed significantly to this new branch of mathematics.

In December 1968, he had one of his first breakthroughs as a scientist. His 'Imaginary Theory' became his first scientific publication. It resulted in a travel scholarship - his first tour abroad - during the course of which, he became one of the most renowned mathematicians in Europe.

Lie's investigations led to one of the major branches of 20th century mathematics, the theory of Lie groups and Lie algebras. Lie died in 1899.



*Marius Sophus Lie*
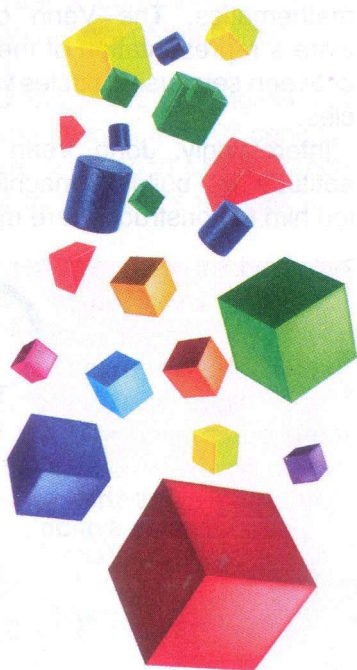
## Why is Georg Cantor one of the superstars of mathematics?

Georg Cantor, a German mathematician, was born in 1845. He laid the foundation for modern mathematics and most of his works have survived to date. The first paper he published dealt with algebraic numbers.

Georg Cantor is famous for discovering and building a hierarchy of infinite sets according to their cardinal numbers. He is also known for inventing the Cantor set, which is now a fundamental theory in mathematics.

Apart from the cardinal numbers, Georg Cantor is also credited for having furthered the study of trigonometry, and transfinite numbers.

When his notion of the Set Theory was recognized worldwide, new areas such as topology and the measure theory were explored. These recent developments signified the importance of Cantor's works.



**STAR FACT**

**Cantor Saying**

Georg Cantor once said 'The essence of mathematics lies in its freedom. In mathematics, the art of proposing a question must be held of higher value than solving it'. This is one of the reasons mathematics has fascinated the greatest thinkers in history.



*Georg Cantor*

This graph is too simple to analyse.
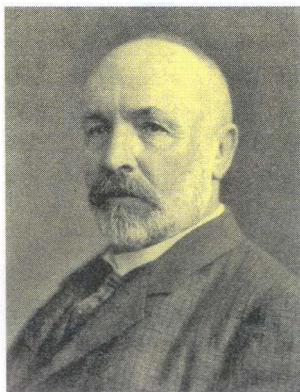


*Gottlob Frege*

## What are the main contributions of Gottlob Frege?

**B**orn in Germany in 1848, Gottlob Frege discovered the fundamental ideas that have made possible the modern development of logic, and thereby, he invented an entire discipline.
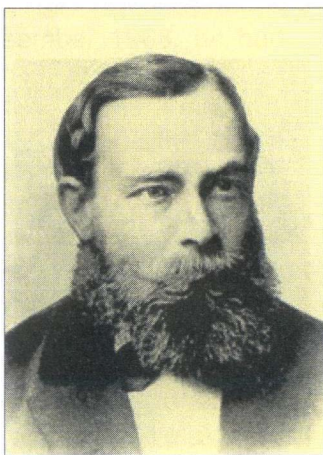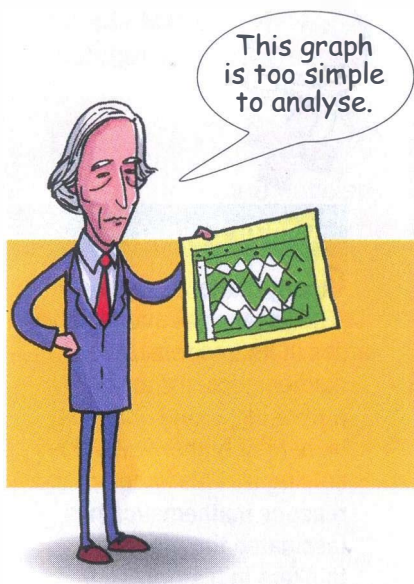
In 1879, Frege published his work in which, for the first time, a system of mathematical logic in the modern sense was presented. No one at the time, comprehended clearly what Frege had done.

Nevertheless, Frege devoted the next decade to producing a series of philosophical articles in which he elaborated his philosophy of logic.

Frege gave a formal definition of cardinal numbers, and showed how basic properties of numbers could be logically derived from it. In 1893, he published 'Basic Laws of Arithmetic', which is regarded as a milestone in the history of mathematics.

**Tell Me Why**

*Henri Poincare*

## Why are Henri Poincare's contributions of great significance?

**B**orn in 1854, French mathematician and scientist Henri Poincare made many original fundamental contributions to pure and applied mathematics, mathematical physics, and celestial mechanics.

Apart from being a well-known mathematician, Jules Henri Poincare also engaged in the study of philosophy. As a mathematician, he discovered and created the field of topology, and studied the continuity of shapes. This would later help him answer a crucial question based on the solar system and its stability. He also contributed to the field of nonlinear systems, and went on to describe the many properties of deterministic chaos.

With his colossal contribution and dedication to the subject, Henri Poincare became a legend. A special group used in physics and mathematics called the 'Poincare group' was named after him.

## Why is Giuseppe Peano considered to be a colossus amongst mathematicians?

Giuseppe Peano was born in 1858 in a farmhouse right outside Cuneo, Italy. When he was a child, his uncle, who was a priest, recognized that Peano was a talented student, and enrolled him in a high school that prepared him for college. After graduation, he entered the University of Turin.

Peano began his mathematical career as an analyst. He wrote over 200 books and papers. He was a founder of mathematical logic and set theory, to which he contributed much notation.

One of the most famous things he is known for is the five Peano axioms, which defined the natural numbers in terms of a set of elements.

From 1892 to 1908, Peano was engaged in writing a book called 'Formulario Mathematico', which contained all theorems and all methods. He is truly a colossus amongst all mathematicians.
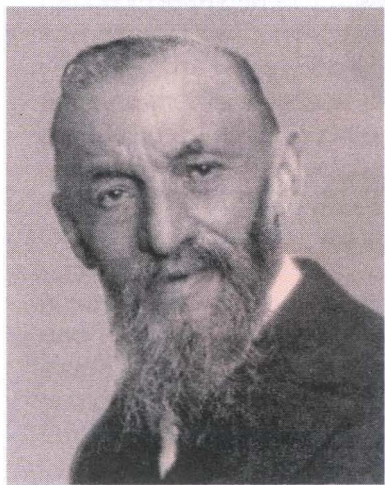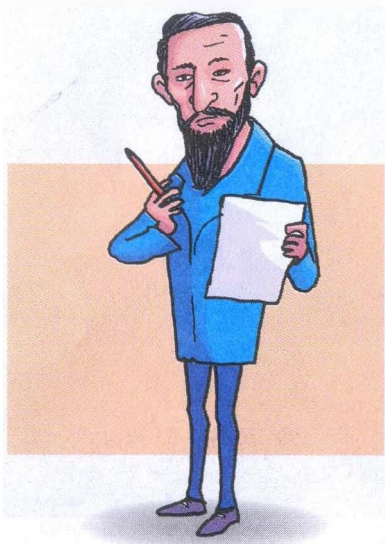


*Giuseppe Peano*

## What do we know about Alfred North Whitehead?

**A**lfred North Whitehead, English mathematician and philosopher, was born in England in 1861.

Although Whitehead was a scientist whose areas of expertise were maths and physics, his outlook towards these subjects were more philosophical than purely scientific.

Whitehead was born in Britain, but lived a considerable part of his life in the US. Whitehead is also famous for co-authoring the historical 'Principia Mathematica' with Bertrand Russell. Bertrand Russell and Willard Van Orman Quine had carried on with their doctoral dissertations under Whitehead's supervision.

Whitehead introduced logic and analytic philosophy in a brand new way. His inquiries into the structure of science provided the background for his metaphysical writings. 'Process and Reality,' was his major work in metaphysics. Whitehead received the Order of Merit in 1945.



*Alfred North Whitehead*

**STAR FACT**

### New Language

**P**eano created a special language called Peano's Interlingua. His plan was that everyone could use this language, but especially the scientific community. It is a simplified version of Latin, and retains its vocabulary.

● *Radha Nair*

## What were the contributions of David Hilbert to mathematics?

David Hilbert, a German, was one of the most influential of 20th century mathematicians. His works helped pave the path for modern mathematical research in the 20th century.

Hilbert was the first to distinguish between mathematics and metamathematics, which is the study of mathematics itself using mathematical methods.

Hilbert's strong foothold in mathematics proved significant in areas ranging from number systems to geometry, and extended mathematics to mathematical physics. His finest research work was his contribution to algebraic number theory. He also wrote the 'Grundlagen der Geometrie' giving an account of geometry as it had developed through 19th century.

Hilbert contributed significantly in establishing important tools used in modern mathematical physics.

*David Hilbert*

## What was the role played by Hermann Minkowski in mathematics?

**H**ermann Minkowski was a renowned German mathematician. His contribution to the development of modern mathematics is immense.

Minkowski created and developed the geometry of numbers, and used geometrical methods to solve problems in number theory, and the theory of relativity.

Minkowski is best known for his work in relativity. His idea of combining the three dimensions of physical space with that of time brought the concept of a four-dimensional space, later known as 'Minkowski space-time'. He discussed this theory through his book 'Space and Time'. The works of Einstein and Minkowski establish the fact that space and time are closely interlinked.

This theory of four-dimensional space-time later provided an inspiration for Einstein's work on general relativity.

*Hermann Minkowski*

### STAR FACT

#### Principia Mathematica

**T**he Principia Mathematica is a three-volume work on the foundations of mathematics, written by Bertrand Russell and Alfred North Whitehead. It is considered to be one of the most important works in mathematical logic of the twentieth century.

## Why is Bertrand Russell one of the intellectual giants of the 20th century?

Bertrand Russell was not just one of the great mathematicians of the 20th century- he was a philosopher, writer, historian, logician, and political activist.

His career began with his publication 'German Social Democracy' which showed his keen interest in politics. He also wrote two books 'The Principles of Mathematics' in 1903, and 'Principia Mathematica', which he co-authored with Whitehead in 1910.

With Guiseppe Peano he was one of the few who recognized the genius of Gottlob Frege and his new system of logic.

Bertrand Russell always believed that ideas could change the world. He was closely involved in many of the events that shaped world politics during the first two-thirds of the 20th century.



## CURIOUS FACT

### Nobel Prize

Bertrand Russell published more than 70 books and around 2000 articles. Though a great mathematician, he won the Nobel Prize in 1950, not for mathematics, but for literature, for he was a giant in this field also.



IDEAS COULD CHANGE THE WORLD
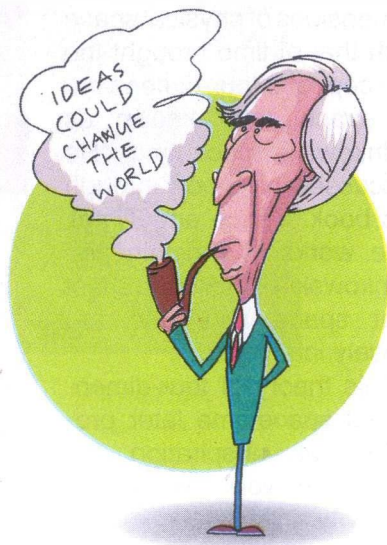
## What is the significance of the work of Tullio Levi-Civita?



*Levi-Civita*

In 1917, an Italian mathematician, Levi-Civita published a paper that became one of the milestones in the history of mathematics. In it, he postulated a law of parallel translation of a vector in a Riemannian curved space.

Levi-Civita was a graduate of the University of Padua, and had outstanding command of pure mathematics, with particularly strong geometric intuition, which he applied to a variety of problems of applied mathematics.

Analytic dynamics was a topic of great interest to Levi-Civita and he did numerous studies regarding the area. He began publishing papers on the subject in 1903, with another important paper appearing in 1906, which strengthened his earlier result.

He was interested in hydrodynamics too, but Levi-Civita's forte was differential calculus and relativity.
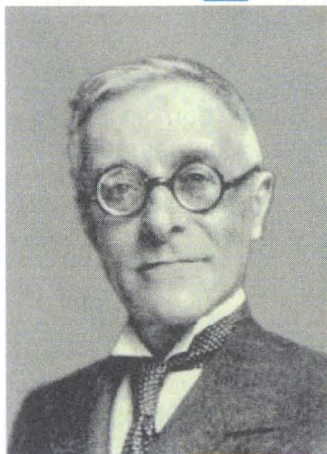
## What do we know about G.H. Hardy?

**G**.H. Hardy, born in 1877, was an English mathematician who made the mathematics world look up to England for his massive contributions in 'pure mathematics'.

Hardy formulated mathematical essays, number theories, and analysed mathematics in a fresh and new way. In the year 1911, Hardy started off an important mathematical journey by collaborating with John Edensor Littlewood in propounding mathematical analysis and analytic number theory.

Hardy also collaborated with Wilhelm Weinberg to come up with the Hardy–Weinberg principle, a basic principle of population genetics. Hardy's involvement in this field made him discover a branch of applied mathematics.

Hardy is also known for being the mentor of the great Indian mathematician Srinivasa Ramanujan.

No, Little Hardy is not studying. He's playing with numbers.

## Why is Brouwer an important name in mathematics?

L.E.J. Brouwer was a Dutch mathematician who lived between 1881 and 1966. He founded modern topology in classical mathematics.

Topology is the study of the most basic properties of geometric surfaces. He also gave the first correct definition of dimension.

In philosophy, Brouwer's brainchild is intuitionism which views mathematics as a free activity of the mind, and is essentially a philosophy of the foundations of mathematics.

Brouwer's ideas seemed to have matured early- in an article titled 'Profession of Faith' and in an essay composed when he was still a graduate student titled 'Life, Art, and Mysticism'.

The work remained the sentimental grounding for Brouwer's intuitionism, and was an inspiration to him throughout his life.



*Brouwer*

## Why is Hermann Weyl an important figure in mathematics?

**H**ermann Weyl, a German, was one of the most brilliant mathematicians of the 20th century. His contributions in the fields of foundation mathematics, harmonic analysis, analytical number theory, and integral equations were remarkable.

Space, time, matter, logic, philosophy, and symmetry were his major areas of work. Weyl also worked on pure mathematics. He wrote a number of books on the theory of groups, and published his findings on them, both technically and generally.

Weyl was interested in generalizing and refining the basic concepts of geometry as well. Like Einstein, Weyl was fascinated by general relativity, and was the first ever to have contemplated merging general relativity with the laws of electromagnetism.



*Hermann Weyl*

## CURIOUS FACT

### Zero

**T**he word 'zero' is adapted from the Arabic word 'sifr'. The word 'cypher'- which means a secret code for communicating- is also derived from 'sifr'.

## What is the significance of Kurt Godel's work?

**B**orn in 1906 in Austria, mathematician Kurt Godel was one of the great names in the scientific and philosophical world of the 20th century.

He published his first two theorems on incompleteness when he was just 25 years old. Godel showed that, no matter how you formulate the axioms for number theory, there will always be some statement that is true of the natural numbers, but that can't be proved.

Godel's discovery undercut the foundations on which mathematics had been built up to the 20th century.

Godel's innovative techniques, which could readily be applied to algorithms for computations, also laid the foundation for modern computer science. Godel also worked on the construction of alternate universes that became models of the general theory of relativity, and created a rotating model of our universe.

Cent per cent incomplete...

*Kurt Godel*
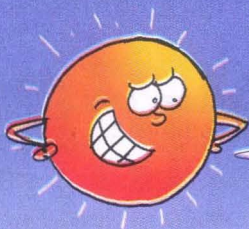
Yes! I'm a great Dynamo and I want payment for my current.

## What are the contributions of Thomas Cowling to mathematics?

Thomas Cowling, an Englishman, studied maths at Oxford University, and published several books on mathematics.

His work paved the way for the discovery of the carbon- nitrogen cycle in 1939. He was also responsible for demonstrating the existence of a convective cone in stars. He explained that the sun may behave like a giant dynamo that produced the immensely powerful electric currents associated with sun spots.



*Thomas Cowling*

Thomas Cowling made very important contributions to the subject of stellar structure, and was one of the first to stress the importance of magnetic fields in astronomical problems.

Cowling was elected to the Royal Society in 1947; he was awarded their Hughes Medal in 1990.
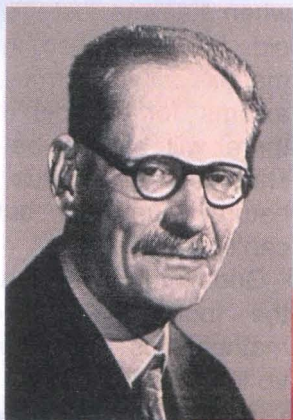
## Why is Klaus Friedrich Roth considered to be one of the leading lights of mathematics?

**K**laus Roth, born in Poland, came to England when he was a young boy. He went to Cambridge, where he was awarded his BA in 1945.

After his college education, he joined the staff at University College, London. He was also elected as Fellow of the Royal Society in 1960. He then served as a professor in Imperial College, London.



*Klaus Roth*

Roth made a remarkable mathematical breakthrough while he was a lecturer at University College. He solved the major open problem of approximating algebraic by rationals in 1955. It was for this work that Roth was awarded a Field's Medal in 1958.

His most significant work has been his book, 'Sequences'. The book represents the study of various integer sequences, such as sequences of prime numbers, and sequences of squares.
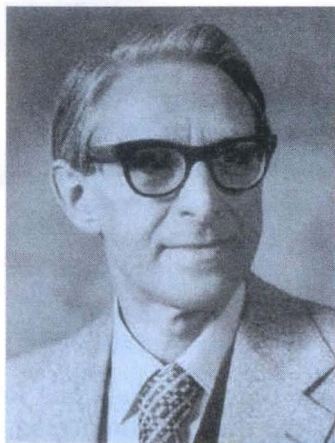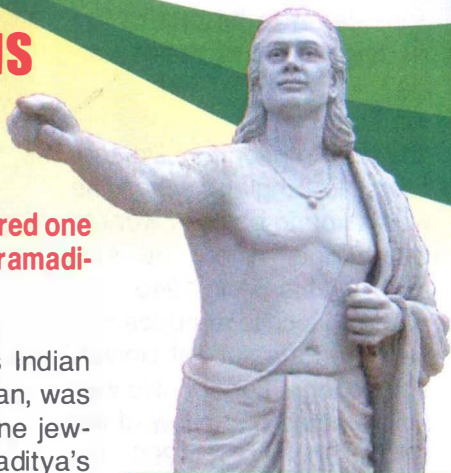
# MATHEMATICIANS OF INDIA

## Why is Varahamihira considered one of the nine jewels of King Vikramaditya's court?

Varahamihira, an illustrious Indian astronomer and mathematician, was one of the navaratnas- or nine jewels- of Chandragupta Vikramaditya's court.

His book Pancha Siddhantika, dated 575 AD, gives us information about older Indian texts which are now lost. The work is a treatise on mathematical astronomy, and it summarizes five earlier astronomical treatises, namely the Surya, Romaka, Paulisa, Vasishtha and Paitamaha siddhantas.

Varahamihira was the first mathematician to calculate that the ayanamsa, or the shifting of the equinox is 50.32 seconds.

Another important contribution of Varahamihira is the 'Brihat-Samhita' which covers astrology, planetary movements, rainfall, and many other subjects of human interest.

## STAR FACT

### Trigonometry

Trigonometry is the study of the relationship between the angles of triangles and their sides. It is a very important branch of mathematics.

## Why is Aryabhata considered one of the greatest mathematicians in history?

Aryabhata, born in 476 AD, was the first of the great mathematicians of Ancient India. He is also known as Aryabhata I. He lived at Kusumapura or Pataliputra in ancient Magadha, or modern Patna.

At the age of 23 years, Aryabhata wrote two books on astronomy -Aryabhatiya and Arya-siddhanta. His major work, 'Aryabhatiya', was a mix of mathematics and astronomy. The mathematical part of the Aryabhatiya covers arithmetic, algebra, plane trigonometry, and spherical trigonometry.

The 'Arya-siddhanta', a lost work on astronomical computations, is known through the writings of Aryabhata's contemporary, Varahamihira. This work contained a description of several astronomical instruments like shanku-yantra, chhaya-yantra, and water clocks of at least two types.

## CURIOUS FACT

### Modus Indorum.

In Medieval Europe, Indian arithmetic was known as Modus Indorum, or the method of the Indians. The ancient Indian mathematician Brahmagupta called multiplication ' Gomutrika'.

Got it! The best place for an axis.
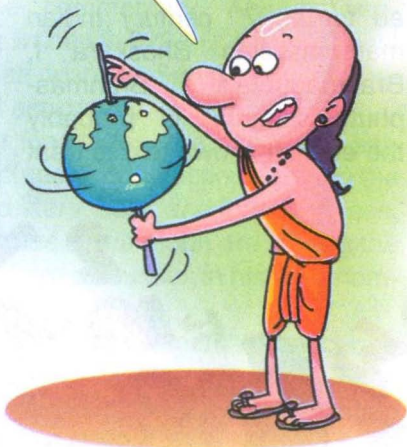
## Why is Brahmagupta considered to be one of the most illustrious of mathematicians?

The great 7th century Indian mathematician Brahmagupta wrote some important books on both mathematics and astronomy.

In his work on arithmetic, Brahmagupta explained how to find the cube and cube-root of an integer, and gave rules facilitating the computation of squares and square roots.

Brahmagupta's genius, though, came in his treatment of the then relatively new concept of the number zero.

Although often also attributed to the 7th century Indian mathematician Bhaskara I, Brahmagupta's 'Brahmasphutasiddhanta' is probably the earliest known text to treat zero as a number in its own right, rather than as simply a placeholder digit.

Another great contribution of Brahmagupta was the concept that there could be such a thing as a negative number, which he referred to as 'debt' as opposed to 'property,' for positive numbers.

Another legacy of Brahmagupta is a formula, now known as Brahmagupta's formula, for the area of a cyclic quadrilateral, as well as a celebrated theorem on the diagonals of a cyclic quadrilateral, usually referred to as Brahmagupta's Theorem.
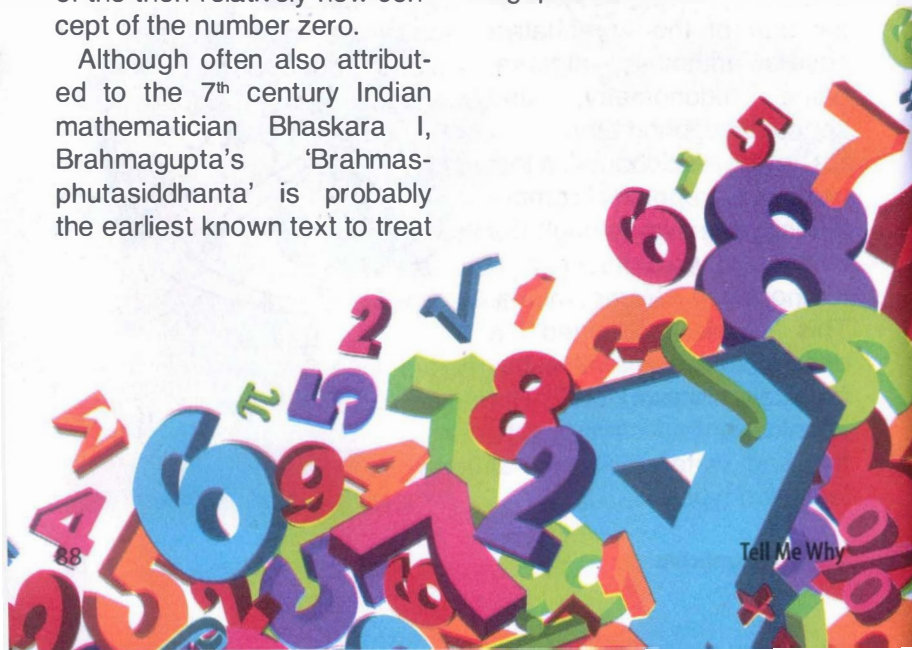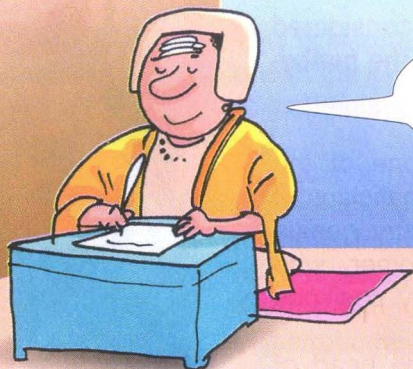
It's not easy to add any thing to Aryabhatiya.

## What do we know about Bhaskara 1?

**B**haskara 1 was an Indian mathematician and astronomer who lived in the 7th century. He was the author of two treatises and commentaries to the work of Aryabhata 1.

His works are the Maha-Bhaskariya, the Laghubhaskariya and the Aryabhatiyabhasya. The commentary, Aryabhatiyabhasya, was written in 629 AD. It is the oldest known prose work in Sanskrit on mathematics and astronomy.

Planetary longitudes, the rising and setting of the planets, conjunctions among the planets and stars, solar and lunar eclipses, and the phases of the Moon are among the topics Bhaskara discusses in his astronomical treatises.

He also includes a remarkably accurate approximation for the sine function, and was the first to write numbers in the Indian decimal system, with a circle for the zero.

## Why is Bhaskara II considered one of the giants of the mathematical world?

**B**haskara II was one of the most famous mathematicians of India. This 12th century genius was also an astronomer, who wrote about planetary positions and eclipses.

Bhaskara II became head of the astronomical observatory at Ujjain, which was the leading mathematical centre in India at that time. He wrote six books.

The topics of his six books are geometry, trigonometry, calculus, algebra, arithmetic, and astronomy.

Bhaskara's works on calculus were written even centuries before Newton and Leibniz, and he was perhaps the first to conceive of differential calculus.

Bhaskara II also wrote Siddhanta Shiromani at the age of 36 in 1150 AD. He calculated the equinoctial shadow at any place, and made new corrections to be applied to the calculation of the time of sunrise.

He is also known as Bhaskaracharya, which means 'Bhaskara the teacher'.

## CURIOUS FACT

### Export Quality

**M**adhava's work had an influence on later European developments in calculus and analysis. His work probably spread to Europe through Jesuit missionaries and spice traders who were active around the ancient port of Muziris at that time.
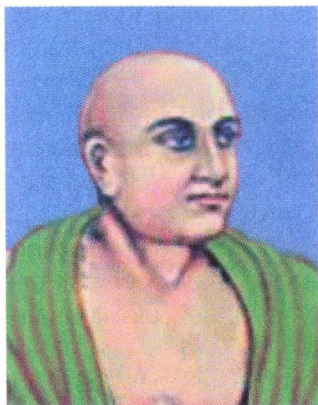
*Madhava*

## Why is Madhava of Sangamagrama one of the key figures in the history of mathematics?

**M**adhava, one of the greatest mathematician-astronomers of medieval India, came from the town of Sangamagrama in Kerala, and was the founder of the Kerala School of astronomy and mathematics in the late 14$^{th}$ century.

He linked the idea of an infinite series with geometry and trigonometry. Madhava effectively laid the foundations for the later development of calculus and analysis.

In astronomy, he discovered a procedure to determine the positions of the Moon every 36 minutes, and methods to estimate the motions of the planets.

In mathematics, his discoveries opened the doors to what has come to be known as mathematical analysis today.

## Why is Srinivasa Ramanujan considered a natural mathematical genius?

**S**rinivasa Ramanujan was a famous Indian mathematician. He died young, at the age of 32, but during his short lifespan he contrib-

*Srinivasa Ramanujan*

uted more to mathematics than many other long established mathematicians.

Ramanujan was born in 1887. He mastered trigonometry by the time he was 12 years old, and developed theorems on his own.

By the age of 17, he was conducting his own research in fields such as Bernoulli numbers, and the Euler-Mascheroni constant.

His life changed for the better in 1913 when he wrote to G.H. Hardy, an English mathematician. Ramanujan worked with Hardy for five years. Hardy was astonished by the genius of the young mathematician, and said that he had never met anyone like him. He published many research papers containing theorems on definite integers, infinite series and other subjects. In 1918, Ramanujan was elected as a Fellow of the Royal Society.He was the first Indian to be honoured in this way.

## What are the main contributions of Mahaviracharya to mathematics?

Mahaviracharya was a great Indian mathematician who lived in the 9th century.

He worked in Mysore in South India, where he was a member of a school of

*Shakuntala Devi*

**S**hakuntala Devi, a child prodigy, was often referred to as a 'human computer' because of her amazing capacity for mental calculations.

She never attended school in her younger days, but grew up to become one of the greatest mathematicians.

During her early years, she shot to fame by mentally calculating one of the toughest mathematical multiplications 10 seconds before the fastest and the most efficient computer of the time.

Her name was listed in the 1982 edition of the 'Guinness Book of World Records' for her outstanding mathematical feat, where she beat the world's fastest computer at multiplying two thirteen digit numbers. She breathed her last on April 21st, 2013.

mathematics. Mahaviracharya was the author of 'Ganita-sara-samgraha'. It consisted of nine chapters, and included all the mathematical knowledge of mid-ninth century India.

Mahaviracharya separated astrology from mathematics. He gave us the terminology for concepts such as the equilateral and isosceles triangle, rhombus, circles, and semicircle. He also attempted to solve certain mathematical problems which had not been studied by other Indian mathematicians. For example, he gave an approximate formula for the area and the perimeter of an ellipse.

*Manjul Bhargava*

### Why is Manjul Bhargava considered an outstanding mathematician?

Manjul Bhargava is the first person of Indian origin to win the Fields Medal. The award is given out every four years by the International Mathematical Union to mathematicians who are under 40, both for their existing work, as well as for their 'promise of future achievement'.

Bhargava is best known for his work on number theory, especially the Gauss composition law. Bhargava is the Brandon Fradd Professor of mathematics at Princeton Uni-

versity, in New Jersey. He is famous for his popular class for students, "The Mathematics of Magic Tricks and Games," in which students explore the mathematical principles behind games and magic tricks.
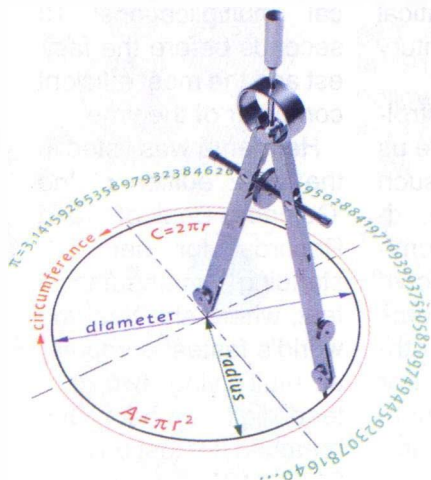
In 2013, Bhargava was elected to the United States National Academy of Sciences.



## STAR FACT

### Multi Talented

**M**anjul Bhargava, besides being one of the most promising mathematicians of our time, is an accomplished tabla player who trained under the tabla maestro, Zakir Hussain. He loves Sanskrit poetry too.

## WINNERS

Winners of the **GK Contest - 17, MUSICIANS**- held in the OCTOBER issue of Tell Me Why.

**1. Neha Gorakh Paswan**
C/o Gorakh Paswan, Nandadeep Apartments, Chinchwad.
**2. Anil Kumar**
Sharma Niwas, Samkhetar Bazar, Mandi, Himachal Pradesh.
**4. Anjali Joshi**
C/o J.D. Vyas, Vyasnagar, Bikaner, Rajasthan.

**3 . Remya C.**
Class IX A,
Ebenezer Residential School,
Ettumanoor, Kottayam.
**5. Sushrut K.N.**
S/o Dr. Narahari,
Veereanarayana Flat, Narayanapur,
Dhrwad, Karnataka.

### GK Contest -17 MUSICIANS - ANSWERS

1. Pandit Ravi Shankar     2. Pandit Shivkumar Sharma
3. Pandit Hariprasad Chaurasia     4. Ustad Zakir Hussain
5. Ustad Bismillah Khan

I Wonder Why?

## How do ants communicate?

**O**bviously, ants do not talk like us humans. Then how do they let their friends know when they have found a big laddoo, or when there is some danger?

Ants actually have a language to communicate, which is totally different from the way we talk. It's a chemical language. Instead of sounds, ants use a chemical to talk! Ants release a chemical known as pheromone while they move. The other ants can detect these pheromones with the help of the tiny antennas on their head. Thus they can follow this scent trail to food or even protect each other in danger. Isn't it an amazing way of communication?

● *Indhu Thomas*
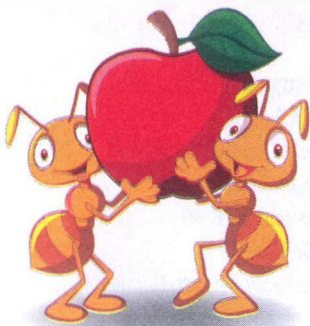
Question sent by:
**Mansi Rode,** Mumbai.

Send us your questions
E mail: **tellmewhy@mmp.in**